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INTRODUCTION.

THE records of experimental work on the improvement of methods of preparation of copra are scattered through a wide range of publications. The present account deals with investigations primarily directed to the study of possible simple methods for adoption by small producers in the Colony of Fiji, having for their object the prevention of rapid deterioration of copra by mould attack.

The Coconut Committee allocated funds for the construction of the sulphuring chamber which was designed by Mr. H. R. Surridge, who carried through the experimental part of the work. Mr. W. J. Blackie conducted the chemical examinations of the material in Fiji, and together these officers have presented an interesting paper which should prove of value not only to Fiji but to workers in other places who are confronted with similar problems.

The Imperial Institute, to whom samples of the copra prepared by Mr. Surridge were referred for further examination, have furnished a comprehensive and valuable report, a summary of which is published. The co-operation and assistance accorded by the Director of the Imperial Institute and his staff are gratefully acknowledged.

A. C. BARNES,
Director of Agriculture.

THE IMPROVEMENT OF FIJI COPRA.

SECTION I—A.

By H. R. Surridge, A.R.C.Sc. (I.), Agronomist, Coconut Committee.

Owing to the high proportion of very low-grade copra produced in and exported from these islands, Fiji copra has been classified as "low grade" on European and other markets. This low-grade copra is mainly produced by the native who employs primitive methods and lacks organisation and the economic urge to produce a first-grade product. His plantations consist invariably of isolated blocks of coconuts, of varying sizes, in all manner of locations, the larger plantations being on the coast line, the smaller blocks scattered along river banks and hill sides. Until recently these plantations had received no cultivation, but under the instruction and direction of the Inspectors of the Coconut Committee this matter has been and is receiving attention. The collection of nuts is spasmodic, depending, if anything, more on the desire for luxuries rather than the want of necessities. When the nuts are collected they are usually old and many have germinated, so that under the best conditions a poor quality copra would be produced, but to the low-grade of nuts used must be added the methods adopted in curing the meat. The native treats his green copra in one of three ways:—

(1) without husking, he splits the nut and lays it open on the ground without any protection from the weather, &c., for the preliminary drying, prior to extraction of the green meat from the shell;

(2) as in (1), except that instead of laying the nut on the ground the halved nut is hung up by the fibre on lines between coconut trees. Under favourable weather conditions a comparatively good quality copra results, but during rainy weather such copra is usually left unprotected with the result that it rapidly moulds and deteriorates;

(3) after splitting the nut the green meat is cut out and placed on reed vatas (shelves) to dry in the sun. Given good dry weather some very good copra is produced, but during rainy weather the copra is either left uncovered or gathered into a heap and any covering material handy, *e.g.*, sacks, corrugated iron, &c., is thrown over it and the whole left indefinitely. Under such conditions moulds and insects soon attack the copra and reduce it to the lowest grade.

The marketing of this product raises other questions and problems, three points of which are here briefly discussed:—

(1) it is customary for some natives to cut green copra, bag it and sell to a dealer. Subsequent curing does not always obviate the result of sweating due to the bagging of the undried material, because many dealers have not the facilities for quick and efficient drying;

(2) the native with "get rich quick" ideas will mix green copra with cured copra with dire results to both. His idea is to make up his weight irrespective of the quality of his produce;

(3) adulteration with foreign matter.

Nos. (1) and (2) still obtain throughout many parts of these islands, but No. (3) is not favoured by the native as much as hitherto. These are some of the factors which have caused Fiji copra to be placed on such a low grade, so much so, that the progressive planter who is producing a first-grade

article finds great difficulty in securing adequate recognition of his superior grade copra owing to the generally poor quality of Fiji copra.

Sulphuring.—In the effort to improve the quality of Fiji copra in general and the native copra in particular, the question of the treatment of the green meat by sulphur fumes (SO_2) has been considered. Some progressive planters sulphur their copra with beneficial results. In other countries sulphuring ($_2$) has been used with good results for some years, and it was considered therefore that provided a suitable equipment could be designed to meet local conditions, the same method might, with advantage, be applied to native copra here in Fiji. For this purpose a portable sulphuring chamber, having a capacity of 1,000–1,500 nuts, the equivalent of about a quarter of a ton of dry copra, was designed Its construction was such that it could be dismantled and assembled quickly, was fool-proof, could be made locally, and could be transported by hand labour from place to place.

It might here be mentioned that the native is in most districts familiar with the use of a sulphuring chamber for medical purposes, and it was considered that with such knowledge it should be an easy matter for him to operate the copra sulphuring chamber.

Having designed such a chamber, it was essential that it should be thoroughly tested, and, in so doing, to obtain all possible and practical knowledge of the resulting product. For this purpose a series of copra sulphuring experiments were designed to demonstrate the effectiveness or otherwise of the chamber for the purpose for which it was to be used in the field, and also the quality of the sulphured copra under varying conditions of treatment. The following paper gives details of the sulphur chamber and the experiments carried out with it.

THE SULPHURING CHAMBER.

The plans and specifications appended, give a good idea of the type of structure used, its portability and its capacity. The chamber consists of a large wooden oblong box of the following dimensions:—

Chamber (internal measurements) .	6′ 6″ by 4′ 6″ by 3′ 4″
Sides	6′ 6″ by 4′ 6″ each.
Ends	4′ 6″ by 3′ 10″ each.
Roof	6′ 8″ by 3′ 10″
Trays	6′ 3″ by 3′ 3″ by 6″ each.
Brace	3′ 4″ by 2″ by 2″

Sides.—6″ by 1″ boards are used for the sides, held at the ends by 3″ by 2″ timbers and strengthened towards the centre by two 3″ by 1″ battens, 15″ apart; 2″ by 2″ timber runs the length of the top between the end 3″ by 2″ timbers. This carries the three bolt holes for attaching the roof as well as strengthening the length of each side. At 1′ from the bottom, on the inside, a 3″ by 1″ batten running the whole length of each side, is fixed. These battens constitute the only set of runners carrying the trays of copra. At one end, about 3″ below these runners, a slotted wooden bracket is fixed to take the tongued end of the brace. This brace prevents the sides from spreading during loading and unloading operations, and is easily removable when it is required to place the sulphur burner in position at the bottom of the chamber. It should, however, be replaced after insertion of the burner and prior to the sealing of the chamber. Bolt holes must be drilled through the 3″ by 2″ timbers at each end and the 2″ by 2″ timber at the top, as indicated on the plan.

Ends.—The ends consist also of 6″ by 1″ boards held together on the short ends by 3″ by 1″ battens. Bolt holes are drilled to correspond in posi-

tion and size with the three holes drilled in the 3″ by 2″ timbers of the sides, as shown on the plan.

Roof.—The timber used for the roof consists of 6″ by 1″ boards, 3″ by 2″ timbers and 2″ by 1″ battens. The structure overlaps the walls to secure an efficient gas-proof box as well as for convenience of handling. Two 3″ by 2″ timbers are used to hold the ends of the 6″ by 1″ boards, and one at the centre for strength. Between these timbers and at the sides, 2″ by 1″ battens are fixed to assist in the alignment of the sides, to improve the gas holding qualities of the chamber and to strengthen. Three bolt holes are required on each side in the positions indicated on the plan and corresponding with the holes drilled in the side walls.

Note.—It is advisable to drill all holes about 1/16th of an inch larger than the size of the bolts to be used. This will facilitate their insertion and removal.

Trays.—The construction is simple and strong with a capacity of 150–200 nuts, without overloading. The trays are made of 2″ by 1″ battens with 3″ by 1″ diagonals, slotted at the centre and where they meet the cross struts, thus giving a very rigid frame. The bottoms are covered inside with ½″ mesh wire netting. The sides and ends consist of a double length of batten separated by an air space of 1″, giving a depth of 5″ inside and 6″ outside. These details apply to six out of the seven trays for this chamber. The seventh tray differs only in depth, being 1″ shallower than the others. This is because the cross timbers of the roof do not allow clearance for the seven trays of a depth of 6″. The wire bottom and the grid sides of these trays allow for free circulation of the gas throughout the chamber. On each of the sides and at the centre of the sides, wooden runners with bevelled edges are fixed to enable one tray to slide easily over the tray underneath. It is advisable to cut the four pieces of wood supporting the sides of the trays ¼″ short since, owing to differences in shrinkage, particularly of new wood, these short pieces are apt to protrude slightly above the long battens forming the sides and interfere with the free running of one tray upon another. Screws should be used in preference to nails wherever possible, particularly in the construction of the trays. On completion of the chamber and trays a coating of creosote is recommended. Bolts with "butterfly" nuts are required. Such nuts facilitate assembling and dismantling, and are not easily lost. It will be noted that the length and breadth of the trays are ½″ short of the internal dimensions of the chamber thus allowing for a certain amount of play and increasing the facility in loading, gas circulation and sealing, an important factor in wet weather.

Method of assembling.—Place the two sides opposite and parallel to each other, sufficiently apart to fix the brace in position. Next take one of the ends of the chamber and bolt it to the sides at the end farthest from the brace. Now place the roof in position and bolt securely. The chamber is now ready for loading.

Loading.—Having filled a tray with freshly-cut copra place it on the runners and push it right home so that it fits just inside the chamber. Repeat with each tray, running the filled tray over the tray underneath, until the chamber is full.

Sulphur charging and sealing.—Remove the brace and place the sulphur burner with its charge freshly lit, as far under the bottom tray as the arm can reach. Replace the brace, bolt the door or end securely, and the chamber is now sealed for sulphuring the green copra. It will be found advantageous to earth up lightly around the bottom of the chamber to

ensure a more perfect retention of the gas during the time the chamber is sealed, particularly if the floor is uneven.

Sulphur burner.—For the purpose of this sulphur chamber, a strong portable burner made out of materials usually obtainable from any storekeeper in these islands was used. It consisted of an enamelled fry-pan to which was fixed four stout wire legs to support, overhead, a large enamelled plate. The object of using enamelled-ware was to avoid the action of the fumes on iron-ware and so ensure long life to the burner. The height of the burner and cover was 9", allowing a clearance of 3" between the top of the burner (enamelled plate) and the bottom of the lowest tray. The plate is considerably larger than the fry-pan, the dimensions being: diameter of plate, 14"; of fry-pan, 9". These dimensions secure efficient covering for the sulphur flames and thus eliminates risk of fire. The utensils used are not essential since benzine or kerosene tins could be adapted for the purpose, but such a burner as described is very strong, durable, easily handled, safe, and in the long run inexpensive.

Effective sulphur burning.—Many users of "flowers" of sulphur for fumigation purposes have experienced difficulty in securing complete combustion of the sulphur. During the course of these experiments similar difficulties were encountered, but were eventually overcome. It was found that as the charge of sulphur increased so an increasing proportion of unburnt sulphur remained in the pan. This as far as could be judged, was not due to lack of air. The first attempt to secure complete combustion was made with dried wood chips soaked in a 1 per cent. solution of potassium nitrate (KNO_3) and mixed with the "flowers" of sulphur. A slight improvement was noted. A similar trial, using potassium chlorate was made, with the same result. The suggestion was then made that a catalyst was probably required to assist the sulphur to burn. A small cast-iron grid was obtained and the sulphur placed on and around it. This was not successful.

Finally, the dried husk of a coconut was taken and some of the fibre teased out and laid on the fry-pan in a rough circle. A layer of the sulphur was placed on this, then alternate layers of fibre and sulphur, until the required amount of sulphur had been utilised. Two layers of each were found sufficient for eight ounces of sulphur. A match was then applied and it was noted that the fibre and sulphur burnt intermittently, slowly but surely, until all the sulphur was consumed, leaving just the charred framework of the fibre. In all burnings carried out in the manner just described, the result was always complete combustion of the sulphur. This represents a simple and effective method of burning sulphur on the plantation, since coconut husks are always obtainable, one husk being sufficient for several burnings. Experiment would indicate the amount required for the particular charge of sulphur being used. This method has since been tried out and adopted on a commercial scale with marked success, no difficulty being experienced in the burning of charges up to 5 lb of sulphur at a time, this amount being the maximum attempted.

COPRA SULPHURING EXPERIMENTS.

To secure results which should be of the greatest service for the conditions obtaining in Fiji, the coconuts used in these experiments represented a fair sample of nuts such as would be used by the native for the production of his copra. The nuts were obtained from native plantations in the Lower Rewa district near Suva. About 8,000 of them were required to make one ton of copra, and they were gathered within a month of the hurricane which visited these islands in December, 1929. Native collection of nuts is, as already stated, spasmodic, hence the heavy proportion of old nuts that were

present amongst those supplied for the making of copra in this experiment. It should be mentioned that in Fiji it is the custom to allow the nuts to fall naturally before making them into copra, while the practice in Ceylon, Malaya and other countries (10) is to cut down the nuts from the trees when ripe.

In experiments 1, 2 and 7, trays of copra made from germinated nuts were set aside for separate observation and chemical analysis, the object being to demonstrate the difference, if any, in the quality of copra made from ripe nuts as against that made by old or germinated nuts. The nuts for experiments 1 and 2 were husked and halved before sulphuring, 1,200 nuts being easily accommodated in the sulphur chamber when cut this way. For the remainder of the experiments the green copra was cut out plantation style, in smaller pieces, fingers, &c. By this method 1,500 nuts were easily accommodated for one sulphur burning. For the subsequent curing of the meat, after sulphuring, old banana packing tables were used on which, green copra was spread. These tables consist of heavy timber tops which did not allow of a free air circulation as in the case of the usual reeded vatas (shelves) commonly in use in these islands.

Further, the season of the year 1930 (January to March) during which these experiments were carried out was the wet or rainy season when drying conditions were not favourable to good copra curing. For this particular period there were 25 days of rain during January, 19 days in February, and 23 days in March, together with a humidity varying between 68 and 100 per cent. Under such circumstances the average time taken for curing was 14 days, the minimum being 9 days and the maximum 19 days. Under dry season conditions the time required in most parts of these islands for copra curing varies from 2½–5 days. It will be seen therefore that for the purpose of these experiments the weather conditions were such as to demonstrate effectively the utility or otherwise of the sulphuring of green copra for the improvement of the subsequent product by mould control, since the longer the time taken and the greater the humidity during the time of curing, represent factors favourable to mould and other growths which bring about serious deterioration in the quality of copra.

In designing these experiments it was the original intention to use varying quantities of sulphur for the same periods of time to discover the necessary charge of sulphur required and the length of time needed to seal the chamber to secure the efficient sulphuring of the green copra. The amounts of sulphur to be used were 4 oz., 8 oz. and 12 oz., sealing the chamber for periods of 3, 6. 9 and 12 hours for each charge of sulphur. In practice it was found that certain of the time periods could be dispensed with, primarily because the sulphur charge was not strong enough to last the time required.

The experiments conducted during this investigation resolve themselves into four series, the first three dealing with the sulphuring of green copra without previous treatment and the fourth dealing with the sulphuring of green copra after a preliminary treatment. While the former confirms previous knowledge as regards the value of sulphur fumes (SO_2) (2) as a preventative of mould growths on copra under reasonable conditions of storage and transport, the latter appears to open up possibilities of treatment for the further improvement of copra rendering it less liable to deterioration by either fungi or insects during drying and storage, and requires to be tried out on a commercial scale to demonstrate its utility. This is discussed later on in this paper. Notes on the condition of the copra at the time of bagging will be found tabulated at the end of each series of experiments.

Series 1.—Four ounces of " flowers " of sulphur were used for the charge in the two experiments comprising this series.

Experiment 1.—Twelve hundred coconuts were taken, husked and split in half, the halves still in the shell—a system in use in the Philippine Islands—were then loaded on to the trays and the whole run into the sulphur chamber. Four ounces of " flowers" of sulphur were put into the burner, carefully lit and, after removing the brace, placed as far as the arm could reach on the floor under the bottom tray. The brace was then replaced, the door bolted into position, and a thin heap of sand placed around the bottom of the chamber to prevent escape of the gas. This work was completed by 4.15 p.m. and six hours later (10.15 p.m.) the door was unbolted and removed and the trays left in the chamber overnight. As a result of this a certain amount of sweating took place. On the opening of the chamber a trace of sulphur fumes was noted, and the wet meat quickly gave an acid reaction to litmus paper. With reference to this latter note, green copra usually gives a slight acid reaction to litmus, so that the rapidity and definiteness of the reaction after sulphuring suggested that some of the sulphur dioxide had been absorbed by the moist copra. On the following day the copra was spread out on tables for sun-drying, as follows:—

(*a*) one tray was set aside for drying without protection from the weather and was left uncovered at night until drying was completed;

(*b*) one tray of this copra consisted of material cut out from germinated nuts. This was set aside for special observation and chemical analysis, otherwise treated as (*c*);

(*c*) the remainder was spread out on the tables for sun-drying and placed under cover at night and during rain until cured;

(*d*) as control copra for this and all other experiments described in this paper, 100 nuts were cut out according to the method adopted for the various experiments, and spread out on a table to sun-dry in the usual way, this copra *not* being sulphured but otherwise receiving the same protection as (*c*) above.

Note.—It often occurs amongst the natives that green copra is cut out and left either on the ground or on vatas without any protection from the weather. It was required to know therefore, what influence such treatment would have on the sulphured article, hence the reason for subjecting one tray of copra in the various experiments to similar conditions.

All copra was carefully raked over each morning after exposure to the sun for about one hour. The copra of this experiment (No. 1) took 12 days to cure, intermittent showers and high humidity delaying drying. Moulds (Penicillium and Aspergillus varieties) appeared on the third day of drying and continued to increase until the ninth day, the growths appearing more persistent and more freely on the sulphured sample as against the unsulphured or control sample. This copra was finally sampled and bagged on the twelfth day of drying.

Experiment 2.—This experiment as regards the sulphuring varied only from No. 1 in that the chamber was sealed for three hours. On opening there was a fairly strong smell of gas. The weather during the period of drying was similar to that of Experiment 1. After four days of sun-drying the moulds Penicillium and Aspergillus appeared and made rapid progress, due to the humid conditions prevailing. Drying was completed in 10 days, when the copra was duly sampled and bagged.

CONDITION OF THE COPRA ON BAGGING—SERIES 1.

Expt. No.	Sulphured. Uncovered (*a*)	Sulphured. Germinated. (*b*)	Covered. (*c*)	Control (not sulphured) (*d*)
1	Appearance fair, some moulds and brown discoloration. Quality poor.	Appearance & colour fair. Some moulds & browning of the copra. Very thin and chippy. Quality fair.	Appearance fair, rather better than control (*d*) although it had moulded freely. Quality fair.	Appearance fair, moulded freely. Quality fair.
2	Appearance bad, moulds very prevalent. This sample wass everely attacked by the copra beetle, (*Necrobia rufipes*) and ants. Quality poor.	Appearance poor, moulds very prevalent. Quality poor.	Appearance fair, moulds present & brown discoloration. Not so good as control (*d*) in appearance. Quality fair.	Appearance fair, moulds present. This appears to be the best copra of this series. Quality fair.

In view of the results obtained with the sulphur charge used in these two experiments, particularly as regards the comparatively weak concentration of the sulphur dioxide gas on opening the chamber after three hours sealing and the mere trace found after six hours sealing, it was considered valueless to proceed with this quantity of sulphur to seal for nine hours and twelve hours, the quantity of gas produced not being sufficient to achieve the desired object, and the longer time within the chamber tending to induce undue sweating of the green copra without beneficial results.

Series 2.—Eight ounces of " flowers " of sulphur was used in the charge for these three experiments comprising this series. In this and the succeeding series of experiments the coconuts were treated as on the usual Fijian plantation by being split with an axe and the green meat cut out in fingers and smaller pieces instead of being left in the shell for the first day or two as in the case of Series 1. By this method the green meat of 1,500 nuts was required to fill the seven trays of the chamber without overloading. Further, it was in this series of experiments that the problem of ensuring the complete combustion of the sulphur was encountered and solved in the manner already described.

Experiment 3.—In this experiment the chamber was sealed for three hours after the burning sulphur had been placed inside. At the opening of the chamber a very strong smell of sulphur dioxide was observed. The copra was taken out and spread on the tables for drying as follows:—Sulphured—(*b*), uncovered; (*c*), covered; (*d*), control (unsulphured).

Note.—No copra from germinated nuts was isolated in this series. This copra took 12 days to dry. Moulds appeared on the third day, but the two following days were fine and dry and it was noted that the moulds did not visibly spread, due undoubtedly to the drier atmosphere with the quicker drying.

From the sixth day until the twelfth, when the copra was ready for bagging, the humidity of the atmosphere increased and delayed drying, with

the result that the moulds increased somewhat. On the twelfth day the copra was sampled and bagged.

Experiment 4.—In this case the chamber was sealed for six hours, and on opening a fairly strong smell of gas (SO_2) was noted. The copra was drawn out and placed on tables for drying in the order noted for Experiment 3. During the time of drying the weather was usually bright, but humidity high, this accounting for the slow drying. Moulds appeared by the fourth day but did not increase. Some browning of the copra as it approached complete curing was noted, particularly amongst that copra obtained from germinated nuts. Curing was completed on the eleventh day, when the copra was sampled and bagged.

Experiment 5.—The nuts used in this experiment had been on hand for 28 days, were ripe when originally delivered, and in the interval many had germinated. The copra produced from this sample can therefore be classed as typical native copra. In this case the chamber was sealed for nine hours, but on opening at the end of that period only a trace of the gas was observed. On due consideration it was decided therefore that to seal the chamber for 12 hours with only a charge of ½ lb of sulphur would be of no practical advantage. This experiment therefore concludes Series 2. The copra was duly spread out to dry, but the weather was unfavourable for the first three days. Moulds appeared on the control sample on the third day, and on the sulphured copra on the fifth day, but in both cases development was slow, so that when the product was bagged on the fifteenth day of drying, moulding of the copra was not particularly marked.

SERIES 2.

Expt. No.	Sulphured copra.		Control (unsulphured)
	(*b*)	(*c*)	(*d*)
3	Appearance, dirty looking sample. Copra beetle (*Necrobia rufipes*) present Quality poor.	Appearance good, some moulds and browning due to the presence of germinated nuts. Quality good.	Appearance good, some moulds and browning, as in (*c*). Quality good.
4	As expt. 3. Quality poor.	As expt. 3, but appearance and quality rather better. Quality good.	As expt. 3. Quality good.
5	Appearance black, charred but flesh appears sound and good. Not attacked by the copra beetle. Quality poor.	Appearance good, very free from moulds but some browning. Quality good.	Appearance fair, but moulded freely. Quality fair.

The result of the experiments in this series indicates that some value may be attached to the sulphuring of the green copra, since, in the last experiment particularly, the quality of the sulphured copra was slightly better than the control.

Series 3.—Twelve ounces of " flowers " of sulphur was used in each of the experiments of this series, the burning being accomplished by using dry coconut husk, as already described.

Experiment 6.—The chamber was loaded with green copra and after the sulphur charge has been lit and placed in position, sealed for three hours. On opening the chamber it was found to be overpoweringly full of sulphur fumes and was unapproachable for some 15 minutes. After the gas had cleared, the copra was taken out and spread on the tables for drying, as follows:—Sulphured—(*b*), uncovered; (*c*), covered; and (*d*), control (unsulphured). During the process of drying some moulds showed on the control on the fourth day, but in the case of the sulphured no moulds were apparent until the copra was ready for sampling and bagging 17 days after the sulphuring. Although unfavourable drying weather occurred during the curing of this sample of copra, the sulphured (*c*) copra remained very white and dried an excellent sample in appearance.

Experiment 7.—This experiment differs from Experiment 6 in that a tray of germinated nuts was set aside for special observation, as in Series 1. This was done in view of the apparent improvement of the sulphured copra in this series. The chamber was sealed for six hours, and on opening a very strong smell of gas was noted. Fifteen days were occupied in curing this copra, moulds appearing on the control on the fourth day, but not on the sulphured copra.

Experiment 8.—In this experiment the chamber was sealed for nine hours and on opening there was a strong smell of sulphur fumes (SO_2). All the trays were taken out and stood one upon another, criss-cross, outside the chamber and under cover during the week-end. This allowed for free circulation of air between the trays whilst standing from the Saturday night until Monday morning. On the fifth day of drying, moulds appeared in quantity on both the control and sulphured (*c*) copra; in the latter case two trays were particularly affected. The copra of these two trays was from old nuts and germinated nuts, and it was not clear whether this excessive moulding was due to (1) the age of the nuts, (2) undue length of time enclosed in the sulphur fumes, or (3) lack of air circulation through the method of stacking the trays after removal from the sulphur chamber. This experiment was therefore duplicated, the description of which will be found under Experiment 8A. By the 10th day of drying (Experiment 8) all moulds appeared to have ceased growth. Sampling and bagging was carried out on the thirteenth day.

Experiment 8A.—This experiment duplicated Experiment 8, for the reasons already given. The chamber was sealed for nine hours, a strong smell of gas being noted on opening the chamber. The copra was spread out in the usual way, receiving protection at night and from rain during the day. Sixteen days were occupied in drying. The control sample moulded freely from the fourth day onwards, black and brown moulds predominating. The sulphured sample remained practically free from moulds until sampled and bagged. The inference drawn from this duplicate experiment as regards Experiment 8 was that the difficulty met with was not due to excessive sulphuring.

Experiment 11.—In the previous experiments of this series there was practically no visible difference in the quality of copra produced by the various periods of sulphuring, viz., three hours, six hours, and nine hours. One other experiment was devised therefore to discover whether a shorter period than six hours would be as effective and thus economise time. For this purpose the chamber was filled with green copra and sealed for 4½ hours. On opening there was a very strong smell of gas. The copra was unloaded on to tables for drying in the usual way. Owing to weather conditions sampling and bagging was not possible until the 17th day.

SERIES 3.

Expt. No.	Sulphured copra.			Control (unsulphured) (*d*)
	(*a*)	(*c*)	(*e*)	
6	Appearance, black and charred but flesh on breaking of a good colour. Quality bad.		Appearance good, bright copra. Practically free from moulds except for those appearing on the "germinated" Quality 1st grade.	Appearance good, some moulds. Quality very good.
7	As 6 above. Quality bad.	Appearance good except for brown discoloration and some mould. Quality good.	As (6) above. Quality 1st grade.	As (6) above. Quality very good.
8	Appearance very bad, red black, & brown moulds prevalent. Quality very bad.		Appearance good, some moulds which appeared to die out on the copra drying. Quality 1st grade.	Appearance fair, moulded freely. Quality good.
8A			Appearance very good, colour pearly white. Quality 1st grade.	Appearance fair, moulded freely. Quality fair.
11			Appearance very good, clean and white, practically free from moulds. Quality 1st grade.	As 8A, above.

This series, judging by appearance only, definitely favours the practice of sulphuring.

Series 4.—This series consists of experiments in which the green copra was first washed in a suitable medium before being subjected to sulphur fumes and then sun-dried.

Throughout the preceeding experiments it was repeatedly noted that copra during the drying process often browns on or near to the edges of the meat, this discoloration not being due to moulds. This is a common complaint amongst planters, whether the copra is sun-dried or kiln dried, and the suggestion has been put forward that this is due to the small amount of sugar deposited by the "milk" as it dries from the meat, the heat of the sun or kiln causing the sugar to caramelise and produce the brown discoloration complained of. As a preventive the idea of washing the green copra after cutting out was carried out in Experiments 9 and 12, of spraying with a chemical solution in Experiments 10 and 13, while that of sulphuring after washing was carried out in Experiments 14, 14A, 15 and 15A described in this series. A further point for consideration was suggested by the Government Chemist, viz., as to whether an economical solution of some sulphur compound could be used for the washing process which, while cleansing the meat from the "milk" and therefore the sugar, would on drying decompose and automatically form a fungicidal film over the copra.

This series of experiments was carried out, using in each case the green meat from 100 coconuts, so that the results obtained may be considered as

indicating possible methods of usefulness where success has been achieved to be developed on a larger scale to demonstrate the commercial value and possibilities. It is worthy of note that the idea of washing and sulphuring has since been developed on a commercial scale with success. This will be discussed further on in this paper.

Experiment 9.—It is generally recognised that copra dried on the beach and subject to the direct sea breeze and spray is invariably of good quality. Also, copra which has been immersed in sea water when spread out to dry in the sun is usually of good colour, appearance and quality. To demonstrate, therefore, as to whether such treatment could be recommended for general use, 100 coconuts were cut out and the green copra washed in sea water and then spread out to dry in the sun. Green moulds appeared from the third day onwards, giving the copra a spotted appearance. While these spots did not increase in size beyond that of a pin's head, the general effect was to give the copra a very poor and dirty appearance. This was due mainly to the fact that these experiments were carried out during the wet season, when atmospheric humidity is high and drying conditions generally unfavourable, as evidenced by the long time required to cure the copra. This copra was sampled and bagged on the seventeenth day of drying.

Experiment 12.—This differs from Experiment 9 in that the copra was washed a second time in fresh sea water. It required 14 days to dry this copra, when it was sampled and bagged. It is to be noted that the copra of these two experiments was not sulphured.

Experiment 10.—In this experiment the green copra was sprayed with a saturated solution of Potassium metabisulphate ($K_2S_2O_5$) by means of a " fly-tox " sprayer, 60 cc. of the solution being used. This quantity applied in this manner was found to be sufficient to ensure perfect wetting of the surface of the green copra. This copra required 19 days to dry sufficiently for sampling and bagging. It moulded freely and represented a very bad sample.

Experiment 13.—Twice the amount of Potassium metabisulphite solution of the same strength as in Experimental 10 was used in this case with a similar result. The solution was applied as in 10 above. It is to be recorded however that on the day of this experiment and after the copra had been sprayed, a whirlwind passed close to the open shed being used for these experiments so that the possibility of increased mould spore infection would occur. This copra was sampled and bagged on the twelfth day of drying in the condition recorded below. The result of these two experiments demonstrated that the particular salt used did not, on decomposition, automatically " sulphur " the copra.

Experiment 14.—In this and the three succeeding experiments some of the washed copra was sulphured while still wet with the washing solution, the charge of 12 ounces of sulphur being used, and the chamber sealed for six hours. In each case, after washing the uncured meat, the colouring matter of the brown testa of the kernel spread across the white endosperm, discolouring it, the discoloration persisting in the dried copra giving it a rather dark appearance. With the copra that was sulphured after washing, the fumes (SO_2) exercised a bleaching effect, destroying the discoloration referred to and producing a meat that was whiter than usual, and which retained this whiteness after drying. Further, it was noticeable that with each of these sulphured samples no moulds were visible and no injurious insects of any description were found although the copra beetle (*Necrobia rufipes*) was present in the other samples. Emphasis to this latter pecularity is given in the section of this paper devoted to the behaviour of the experi-

mental copra in store. The copra of this experiment was washed in a 10 per cent. solution of washing soda (Na_2CO_3), a quarter kept for control, the remainder being sulphured for six hours, using a charge of 12 ounces of sulphur.

Experiment 14A.—This experiment differred only from Experiment 14 in that a 5 per cent. solution of washing soda was used.

Experiment 15.—In this experiment a 5 per cent solution of caustic soda (NaOH) was used, otherwise the same procedure was adopted as in Experiment 14.

Experiment 15A.—This experiment varied from Experiment 15 in that a 2½ per cent. solution of caustic soda was used. The copra produced in these four experiments was ready for sampling and bagging after nine days drying.

SERIES 4.

Expt. No.	Washed.		Control (not washed).
	Sulphured.	Not sulphured.	
9		Seawater Covered—colour poor, moulded freely, green moulds prevalent. Uncovered, colour black, due to mould (*Aspergillus niger*). Quality of both lots, very poor.	As 8A. Quality fair.
12		As expt. 9 in both cases.	As 8A.
10		Pot. metabisulphite ($K_2S_2O_5$) Colour very bad, moulded freely blacks and greens Quality bad.	As 8A.
13		Colour very bad, worse than expt. 10, all moulds and beetles. Quality very bad.	Appearance fair, some moulds and browning. Quality good.
14	Appearance very white, sound clean copra. No moulds, discoloration or insects of any kind. Quality extra 1st grade.	Appearance fair, some greenish discoloration from the epidermis. Slight moulding, some copra beetles. Quality 1st grade.	As 13. Quality good.
14A	Appearance not so bright as 14 above. Quality extra 1st grade.	As 14 above.	As 14 above.
15	As 14 above except for slight browning on many pieces. Quality extra 1st grade.	Appearance dark due to staining from epidermis. Slight moulding, some copra beetles. Did not dry to the usual crispness as in the other samples. Quality 1st grade.	As 14 above.
15A	Appearance not quite so good as 15 above. Quality extra 1st grade.	As 15 above.	As 14 above.

From the results obtained in the washing experiments of this series it is of interest to note here that the idea of washing the copra before drying has been put into operation by E. Duncan, Esquire, at his Mua Estate, Taveuni. The copra is brought to the kiln for drying, being first weighed and then tipped on to a wire-bottomed tray under which is a draining pan. Fresh water at about 80° F., and under a natural pressure of 35 lb per square inch, is sprayed on to the green meat by means of a hose fitted with a coarse nozzle. All muck and the residue of "milk" is washed from the copra. After washing, which under this method occupies only two or three minutes, the copra is shot down on to the trays underneath and run into the kiln where in the first four hours of heating it is subjected to sulphuring. When dry this sulphured copra is exceptionally white and clean and commands a premium at the hands of the copra buyer.

CONCLUSION.

Series 1–3.—Copra sold in the various markets of the world is bought more on its appearance than on its oil content. From the buyers' point of view a copra of good bright and clean appearance will give a better quality oil than a copra that is dirty, mouldy and infested with insects; the better the quality of the oil the greater the value of that oil. In judging the copra produced in the various experiments detailed, appearance has formed the basis of quality, in other words the copra has been judged from the standard of the copra buyer.

In the section devoted to the analysis of the copra by the Government Chemist will be found a standard of quality based on those analyses, but which generally follow or confirm the standard based on appearance.

As already stated, the purpose of the experiments was (1) to test out the portable sulphuring chamber, (2) to find the minimum quantity of sulphur required to secure effective sulphuring in this chamber, and (3) to study the sulphured copra.

(1) *The Chamber.*—From the results obtained in the four series of experiments undertaken it can be said that the sulphur chamber was effective for the purpose for which it was designed. It was assembled and dismantled within 30 minutes by unskilled labour, it could be readily transported by hand labour, was easily manipulated and was gas-tight.

The Sulphur.—The minimum sulphur charge for effective sulphuring was not discovered until after Experiment 5 of Series 2. This experiment gave the first indication that sulphured copra was by appearance, rather better than ordinary sun-dried copra as shown by the control sample.

The experiments of Series 3, demonstrated that the condition of effective sulphuring had been reached both as regards quantity of sulphur required and the time necessary for the sealing of the chamber. The minimum charge was found to be 12 ounces of sulphur and the time necessary for the operation three hours. There appeared to be no difference in quality of the copra that was sulphured for three hours as compared with that sulphured for nine hours (Series 3). The suggestion here is that the strong initial concentration of gas produced by the method of burning was sufficient to sulphur effectively the copra within the first three hours of sealing the chamber.

The sulphur burns very readily during the first hour, quickly filling the chamber with fumes. After the first hour the rate of burning decreases until the mass just smoulders but the gas then produced appears to be sufficient to maintain the concentration for another hour or so, after which the gas gradually escapes, hence the conclusion drawn from the experience

of Series 3 is that effective sulphuring can be accomplished in the chamber under test by 12 ounces of sulphur in three hours of sealing.

(3) *The copra.*—For the purpose of observation the copra produced by the preceding experiments was divided under the heads:—

(*d*) control (not suplhured) and sulphured, the latter being subdivided into (*a*) uncovered, (*c*) covered, and (*b*) germinated, these subdivisions representing, in the two former, differences of treatment during drying, and in the latter a particular type of copra.

(*d*) *Control Copra.*—One outstanding feature of this copra was the regularity with which moulds appeared on the third and fourth days of drying on each sample of control copra. Taking into consideration the length of time required at the particular season of the year to effectively cure this copra, the quality at the time of bagging may be considered as "fair merchantable sun-dried" and represented a better sample than is the case with copra produced by the average native. This improvement of quality was due entirely to the attention given it during the long drying period, viz., of protection at night and from rain, and demonstrates how with little effort, "fair merchantable sundried" copra may be produced in place of the poor quality that results from lack of attention and interest during the drying period. Nevertheless this copra was inferior in appearance and quality to the sulphured copra obtained in the experiments of Series 3.

(*c*) *Covered.*—An indication of the value of sulphuring was first noted with Experiment 5 of Series 2. In Series 3 definite improvement was noted when the sulphur charge was increased to 12 ounces, the copra appearing whiter, and during the drying remaining freer from moulds than in the case of the control (*d*), and of a higher standard of quality than any native copra or even that of many European planters. With a reasonable percentage of moisture on the green copra the sulphur fumes (SO_2) not only exercise the desired fungicidal effect but also bleach the copra, thereby adding considerably to the appearance of the dried copra. The difference between the various copra samples of Series 3 was not manifest in the appearance of the copra, all being apparently of the same quality.

(*a*) *Germinated.*—The copra obtained from the germinated nuts during these experiments received the same attention as (*c*) and (*d*), viz., that it received protection from rain and at night, the cover consisting of an open shed or an open garage. This type of copra is invariably thin and when dry becomes very brittle. It is greasier to the touch than copra prepared from the ripe nuts, a feature which is due to the fact that during the process of germination and the successive growth of the young plant the enzyme or enzymes which assist in that process by attacking the endosperm of green copra meat, break down the cellulose tissue and thus release the crude oil. It is this oil that gives the impression of excessive greasiness as compared with copra from ordinary ripe nuts.

In the three experiments allotted to this type of copra, in two cases—Experiments 2 and 7—the copra was definitely of poorer quality and appearance than either of the normal samples as expressed by sulphured (*c*), or control (*d*). In the case of Experiment 1, the difference was not sufficient definitely to mark it as below the standard of sulphured (*c*) or control (*d*). The conclusion therefore is that the use of germinated nuts for the purpose of copra making tends to lower the quality of the copra produced whether the copra is sun-dried or first sulphured and then sun-dried, and should therefore be avoided. With the proper and regular collection of coconuts throughout the plantations the presence of germinated nuts would be reduced

to a minimum and another cause for the production of poor quality copra removed.

(*a*) *Uncovered.*—As already explained in the early part of this paper often no protection from the weather is accorded by the native to his copra during the process of curing. A small section of each experiment therefore was set aside under similar conditions and the result noted. One curious feature of this experiment was that as the sulphuring increased in efficiency so this particular copra became more and more charred in appearance and poorer in quality. Further it appeared to become more attractive to the copra beetle (*Necrobia rufipes*). The conclusion to be drawn from this experiment is that sulphuring does not improve copra which is neglected during the drying period. It is possible however that with the man who decides to improve his copra by sulphuring but fails to give that copra reasonable care during the subsequent drying will have the result of his neglect so apparent in the sulphured article as to compel him to give the required attention, and so secure the full benefit of the sulphuring operation to the further improvement of the copra.

Series 4.—The conclusions just arrived at dealt with the first three series of experiments. Series 4 deals with a set of impromptu experiments which, owing to the few nuts available, serve as indications of possible treatments of green copra which might prove of economical importance.

(1) *Sea water.*—It is known that sea water does improve the appearance of copra when quick sun-drying can be effected, but Experiments 9 and 12 suggest that it is more injurious than beneficial to copra when drying conditions are not favourable.

(2) *Potassium metabisulphite* ($K_2S_2O_5$).—The anticipation of automatic fungicidal action by this salt on copra did not mature, the resultant product being badly attacked by moulds and of very poor quality.

(3) *Washing-soda* (Na_2CO_3) and *Caustic soda* (NaOH).—The results obtained by the use of these two substances, particularly in Experiments 14 and 15 when after first washing in the solutions, the copra was then sulphured and cured, were startling, the washing-soda (Experiment 14) being slightly ahead of the caustic soda in appearance, but the difference was so slight that in grading they were classified as the same. It was however in storage that difference arose in favour of the washing-soda treatment, for the copra thus treated had, during the 4½ months of storage, resisted all mould and insect attack, and this in the midst of other copra that was badly infested with copra beetle (*Necrobia rufipes*), other insects and moulds. Some of this copra, after 10 months in store, was examined and found to have turned rather yellow in colour and to have sustained some attack by insects. On steeping some of this copra in water for two or three days, the water was examined and found to contain sodium sulphate, suggesting that part of the reaction occurring during the sulphuring process resulted in the formation of this salt which not only acted as a fungicide during drying and in storage, also appeared to have acted as an insecticide for this particular sample (Experiment 14) at the same time. Sodium sulphate is recognised as injurious to certain fungi, *e.g.*, smuts and bunts, so that the result attained here suggests a possible extension of its usefulness.

In conclusion therefore it may be stated that the treatment carried out in Experiment 14, namely, to wash the green copra in a 10 per cent. solution of washing-soda (Na_2CO_3) and then subject it while wet to sulphur fumes seems to offer possibilities for commercial use, its advantages being:—

(1) facility and cheapness with which washing soda-can be obtained;
(2) the clear and clean appearance and the high quality of the finished product;

(3) the fact that such treatment by preventing mould and insect attack would conserve the weight of copra and therefore oil produced and exported, to the advantage of the producer; and
(4) that no complications would arise with reference to machinery, &c., through the presence of minute quantities of sodium sulphate on the copra.

SECTION I—B.

Storage.

Introduction.—On completion of the foregoing experiments it was the intention to ship the experimental copra to the Imperial Institute, London, by the first direct boat, and for this reason the weighing of the copra was left until the time of shipment, which was expected to be at an early date. Owing to no boat being available before the writer had to leave Suva, shipment was not made until some five months later. In the following section of this paper therefore the omission to weigh the copra when placing it in store is regretted for it has prevented the obtaining of figures which would have recorded actual losses due to evaporation and insect damage, &c., as well as emphasised the value or otherwise of certain treatments.

Reference to the various indexes available in the Departmental library gives no record of work dealing with the losses incurred by copra during storage. Amongst the records of the Government Chemist, however, were found particulars of storage experiments dealing with losses by evaporation and deterioration through the increase of f.f.a. of the copra, which had been carried out by his predecessor, C. L. Southwell, B.Sc. A copy of this paper is appended so that all available information dealing with these various losses in storage may be placed on record.

On completion of the foregoing experiments the dry copra was sampled and bagged. The method of sampling adopted was that generally known as "quartering," the various types of copra produced being thoroughly mixed and quartered until 3–5 lb of that copra remained. The usual copra bags of commerce were used for bagging both samples and bulk copra. In the case of the former, the large bags were cut into four sections, each section being made into a miniature copra bag capable of holding about 7 lb of copra. The bagged copra was stored by courtesy of Mr. J. P. Tarby, Manager of the Government Rice Mill, in the old Customs Shed, Suva. This shed is a wooden structure with the usual corrugated iron roof, but it is used mainly for the storage of rice, for which purpose the floor is covered with a series of wooden gratings made out of 3 in. by 2 in. timber. These gratings allow for air circulation under the rice or copra stack and also help to reduce rat damage. Such gratings are not usual in copra stores in Fiji, and therefore represent the difference in the storage of this copra as against that in the usual commercial store. The copra was placed in this store on March 12, 1930, was examined July, 31 1930, 4½ months later, and shipped to London on August 18th, 1930, for examination, analysis and report by the Imperial Institute, whose report is awaited with interest.

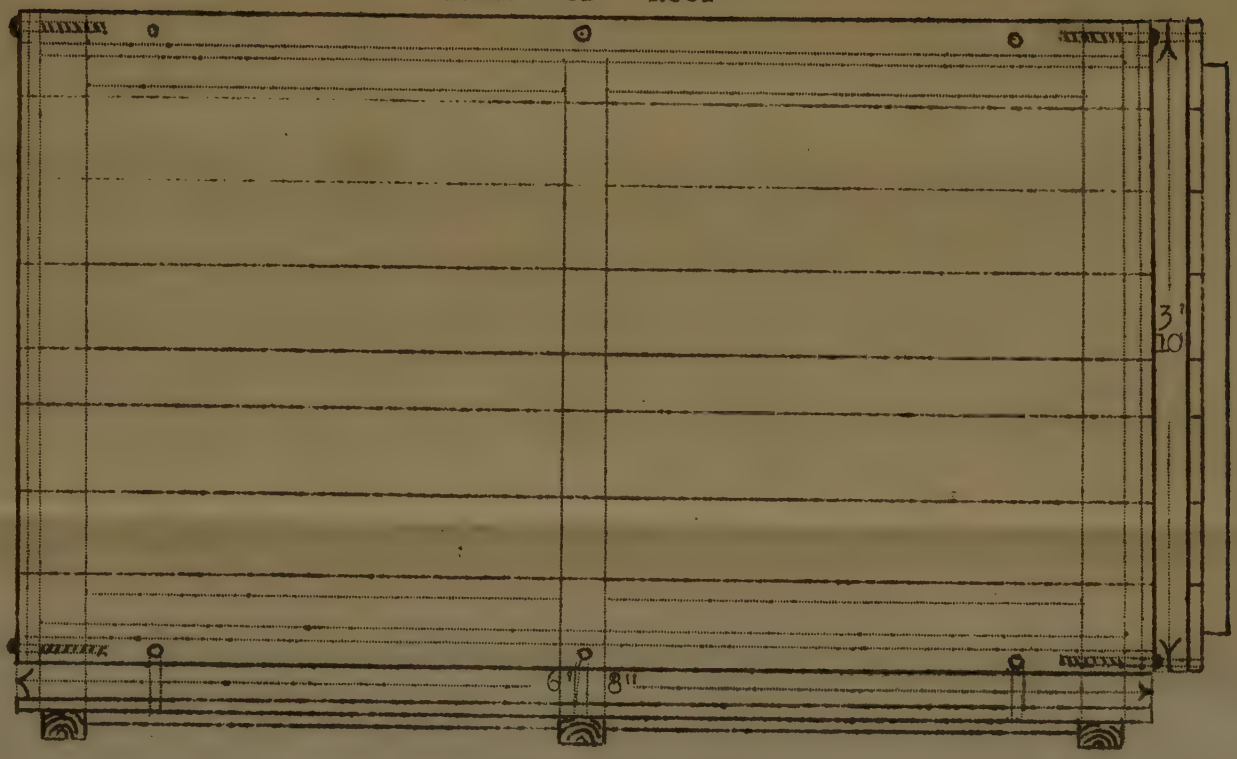
The stores used for copra in Suva by the copra merchants are usually well-built iron or concrete buildings with concrete floors, well ventilated and dry and in close proximity to the wharf. At the small stores owned by Chinese and Indians, scattered throughout these islands, the copra is stored in a wooden or iron shed on either a wooden or earth floor. As the dry copra is brought to these stores by the producer it is weighed and dumped in a heap on the floor of the copra shed, if green copra is brought it is also weighed

and then spread on the storekeeper's vatas, and when more or less dry, transferred to the copra shed and mixed with the copra already there to be bagged when required for shipment. The quality of this copra is invariably poor, due to lack of care and attention given either by the producer and/or storekeeper during drying and storage, for such heaps are usually alive with maggots, weevils, copra beetles, ants, &c. The loss occasioned by the presence of these insects is unknown and must constitute a serious item in the economy of copra production. The condition therefore of the experimental copra tabulated below, is of interest, particularly where such is compared with that which passes through the stores just referred to, viz., those of the Indians and Chinese:—

Expt. No.	Sulphured.			Control. (*d*)
	(*a*) Uncovered.	(*b*) germinated.	(*c*) Covered.	
1	As (*c*).	As (*c*).	Appearance and colour bad. Badly Infested with beetles—*Necrobia rufipes* and *Calandra oryzae* (?). Lot of frass. Quality bad.	Appearance good, slight browning otherwise as (*c*). Quality bad.
2	As above, brown discoloration.	As above.	Appearance and colour fair. Badly infested as above. Quality bad.	As above.
3	As (2) above.		As (2) above.	As (2) above.
4	Appearance and colour bad, infestation bad. Quality bad.		Appearance fair, colour good, but infestation bad. Quality bad.	As above.
5	Appearance and colour bad, infestation bad. Quality bad.		Appearance and colour good, Infestation fair. Quality good.	Appearance and colour bad, infestation bad. Quality bad.
6	Appearance and colour fair, but infestation very bad. Quality bad.		Appearance and colour nearly as good as (5). Infestation bad. Quality fair.	Appearance and colour fair. Infestation bad. Quality fair.
7	Appearance and colour bad, infestation bad. Quality bad.	Appearance and colour good, infestation fair. Quality good.	Appearance and colour good, infestation fair. Quality good.	Appearance and colour good, infestation bad. Quality fair.
8	As above. Quality bad.		As above. Quality good.	Appearance and colour bad, infestation very bad. Quality bad.
8A	Appearance and colour fair, infestation very bad. Quality bad.		Appearance and colour very good, infestation fair. Quality good.	As (8) above. Quality bad.
11			As above (8A).	As above (8A).

COPRA SULPHURING CHAMBER.

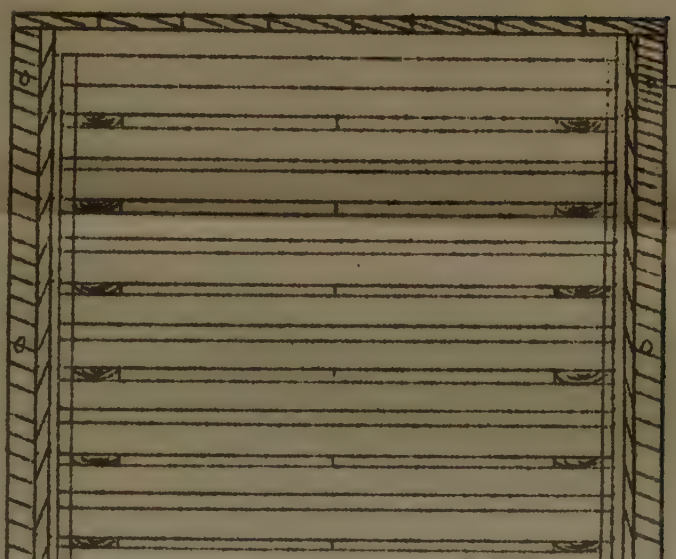
Plan of Roof



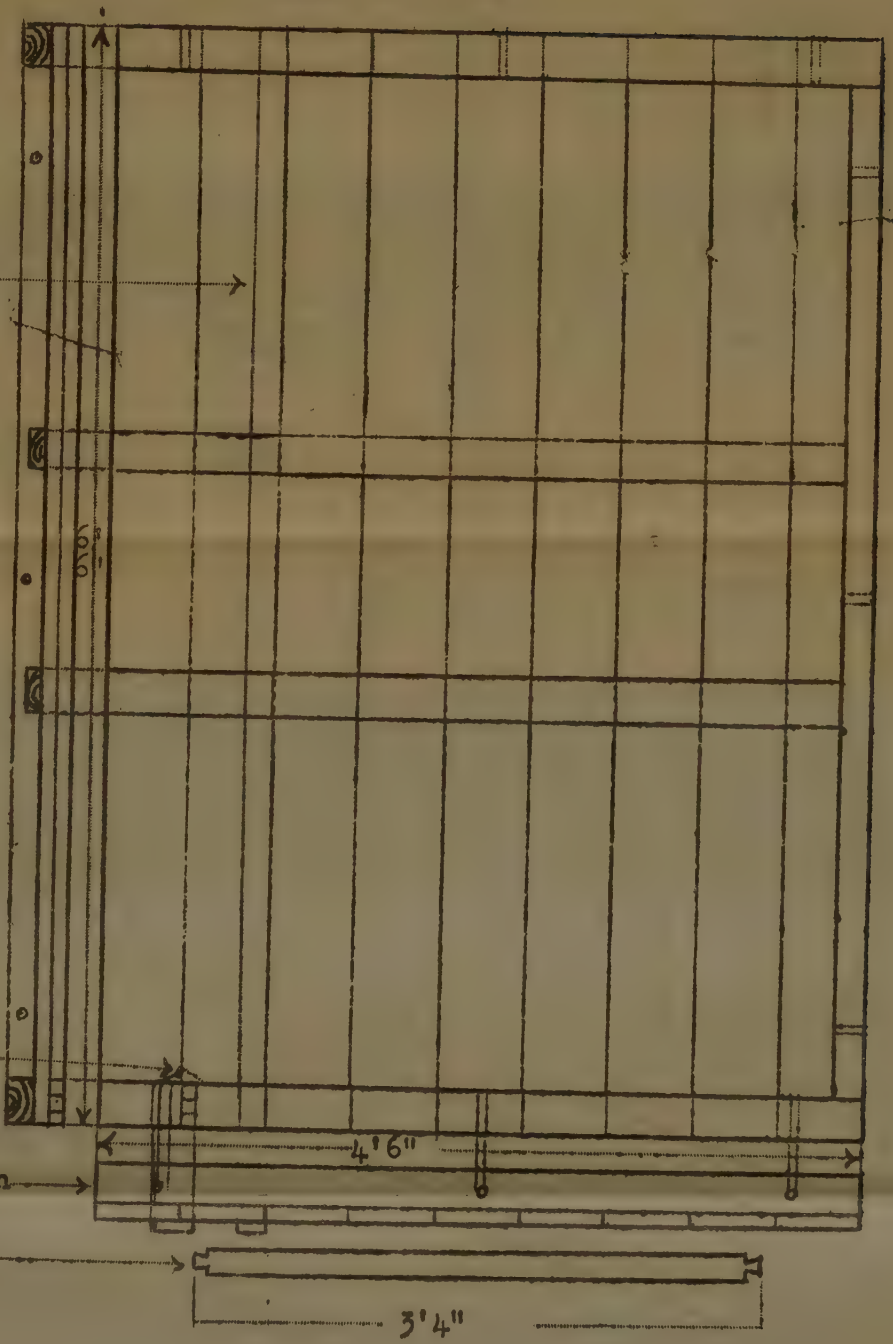
Side Elevation

Museum (a.g. 5-91

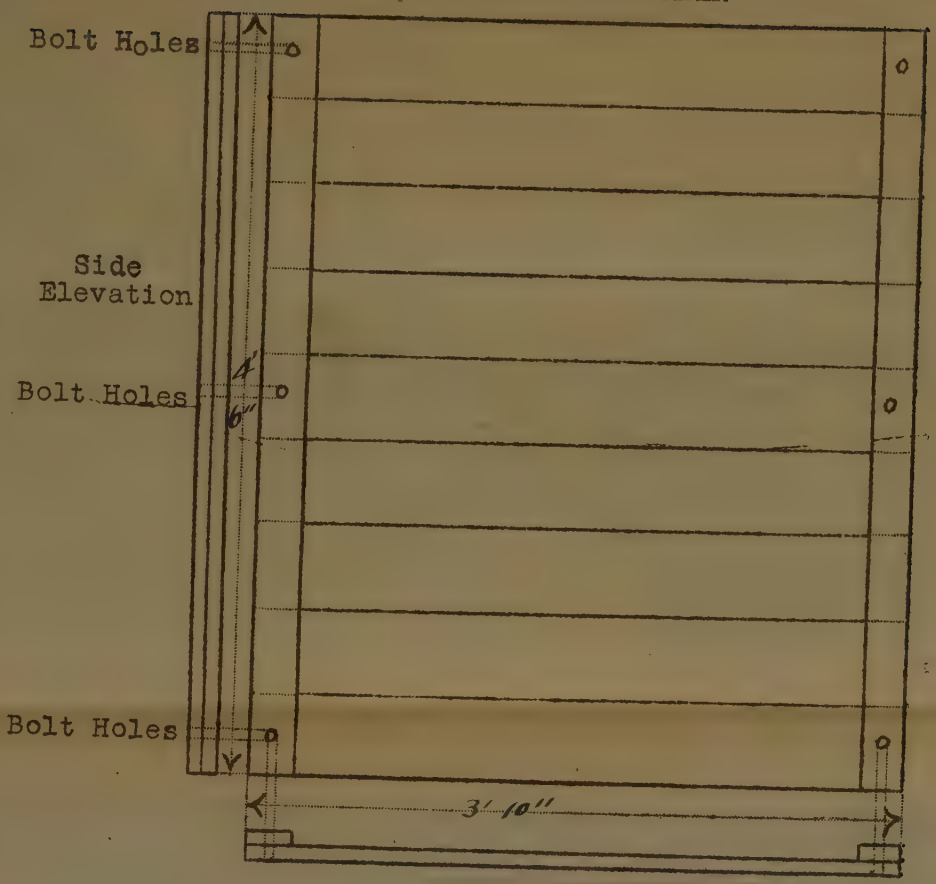
SULPHUR CHAMBER LOADED
One end open.



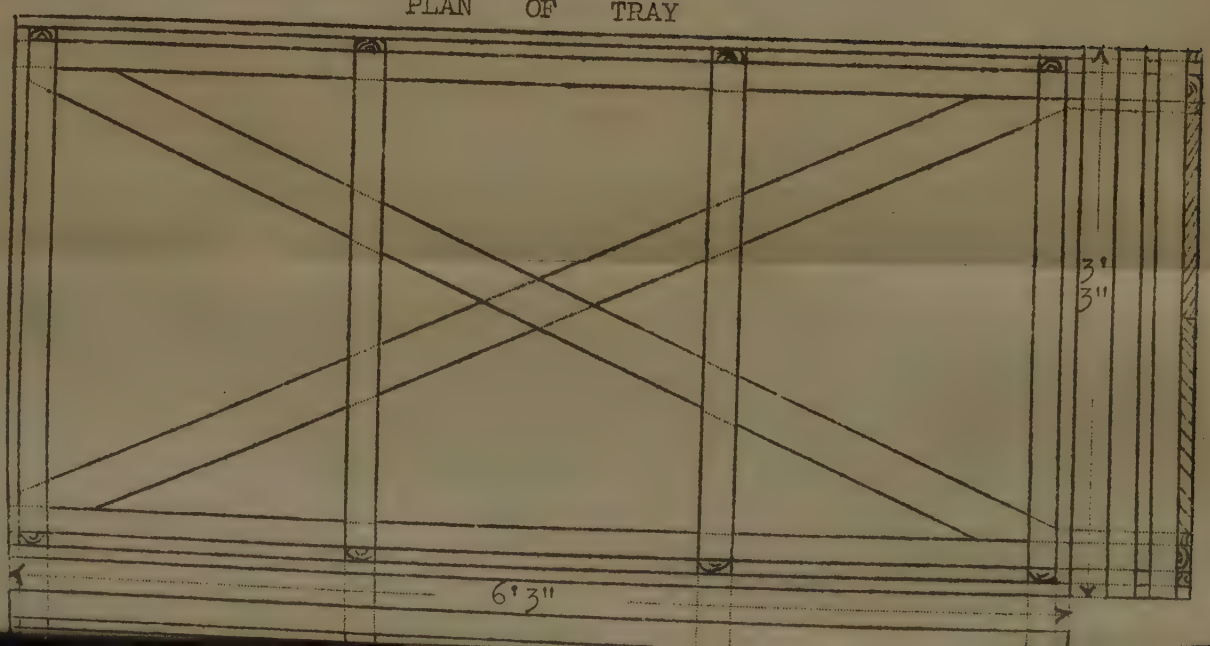
PLAN OF SIDE

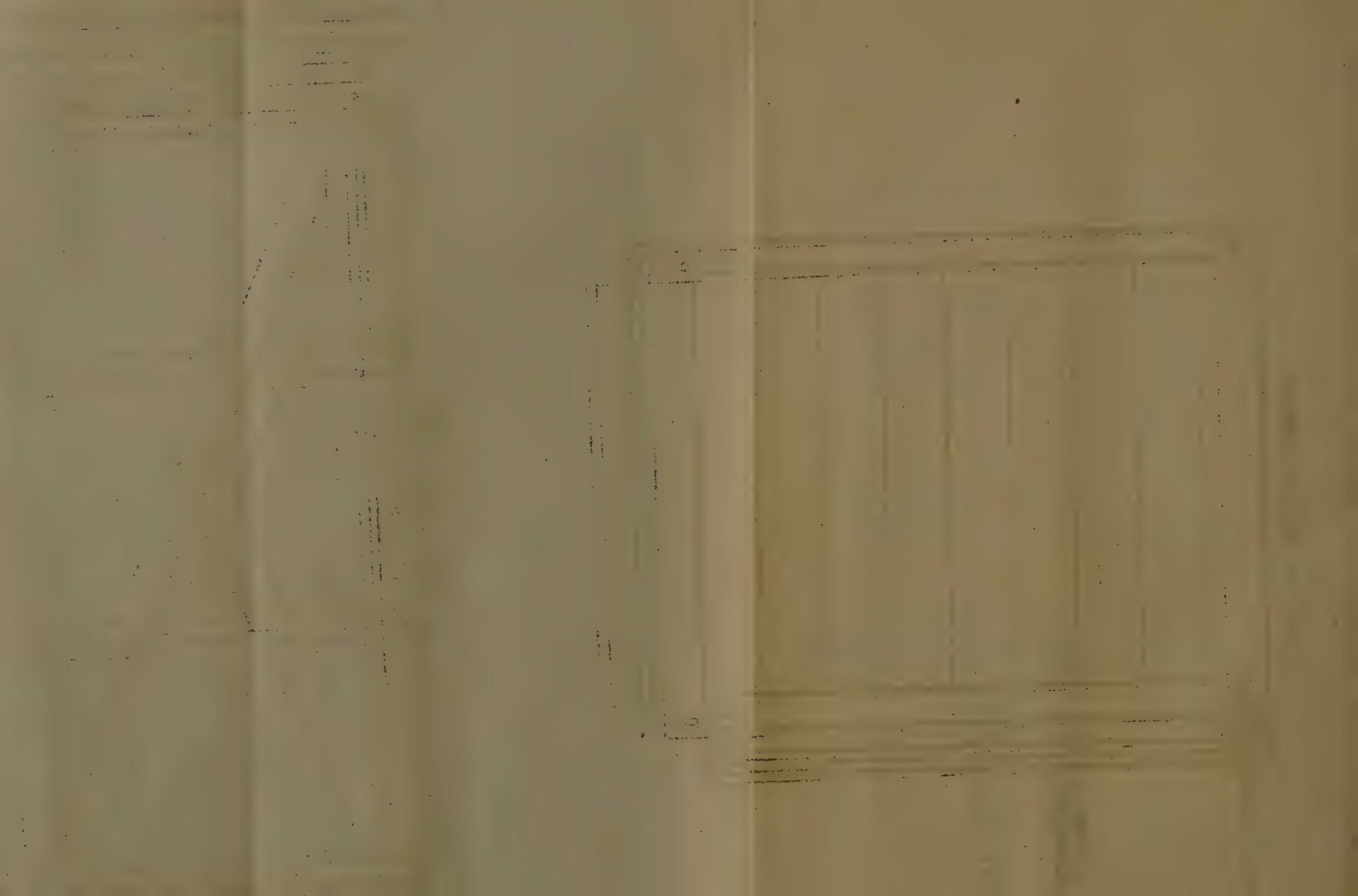

Bolt Hole
Runner for Trays
Side Elevation
Sockets for Brace
End Elevation
Brace
4'6"
3'4"

PLAN OF END OF CHAMBER



PLAN OF TRAY





SERIES 4.

Expt. No.	Washed.			Control.
	Uncovered.	Covered.	Washed and sulphured.	
9	Appearance, colour infestation, very bad. Quality bad.	Appearance and colour fair, infestation bad. Quality bad.		Appearance and colour bad, infestation bad. Quality bad.
12	As (9) above.	As (9) above.		As (9) above.
10		Appearance, colour and infestation, bad. Quality bad.		As (9) above.
13		As (10) above.		As (9) above.
14		Appearance very good colour pearly white, infestation bad. Quality 1st grade.	Appearance and colour excellent. Infestation NIL. Quality extra 1st grade.	Appearance and colour fair, infestation bad. Quality bad.
14A		As (14) above.	As (14) above except slight infestation. Quality practically extra 1st grade.	As (14) above.

Expt.	Washed.		Control.
	Covered.	Washed and sulphured	
15	As 14 above. Quality 1st grade.	As 14 except for very slight infestation. Quality as 14*a* above.	As 14 above. Quality bad.
15A	Appearance and colour good infestation bad. Quality good.	Appearance and colour good, infestation fair. Quality 1st grade.	As 14 above. Quality bad.

Discussion.—Reference to the above table supports the observation made in Section I of this paper, namely, that an approach to effective sulphuring was first noted in Experiment 5, for in the condition of the copra in store it is the sulphured and protected copra of this experiment that shows to advantage over the control copra, both as regards appearance and infestation by insects, and it is noted that in each of the succeeding experiments of Series 2 and 3, that with the exception of Experiment 6, the sulphured and covered is of better quality—judging by appearance and amount of infestation by insects—than the control samples. The suggestion here is that not only does the process of sulphuring assist in checking undesirable mould growths during drying and storage but that it exercises insecticidal properties also during those periods, particularly in the latter.

In Series 4, however, Experiments 14 and 15, not only achieved the purpose of this series of experiments, but when the washed copra was duly sulphured the dried product was found not only of excellent colour and free

from mould attack, but to have also been immune from insect damage during the 4½ months it was in store whilst still retaining its excellence of colour and freedom from moulds. Of the two experiments named, No. 14—that washed in washing-soda (Na_2CO_3) solution and sulphured—may be considered the most successful because no insect attack was discernable, whilst a slight attack was noted in the case of No. 15, where caustic soda (NaOH) was used. Further, in the case of Experiment 14, this is a more practical proposition from the planters' point of view, washing-soda being readily obtainable, it requires no special containers for transport purposes, and is cheap, whereas caustic soda rapidly deteriorates in humid climates, would require to be packed in special containers, is more expensive and not so easy to handle. The result obtained therefore in Experiment 14 is of importance in that it suggests a possible method of preventing losses due to insects when copra is placed in store.

On examination of this experimental copra, the whole was carefully screened and the frass obtained collected and weighed. Frass is defined, entomologically, as excrement. The frass obtained therefore represented an unknown quantity of destroyed copra, so that the results of the following calculations must be considered only as a rough approximation to the truth, especially as the frass was from two or three insects. In the case in point, 81 lb of frass was recovered from 25 cwt. 3 qrs. 2 lb of copra, equal to a loss of 2·9 per cent. in terms of frass. Assuming, however, that to produce one pound of frass 2 lb of copra were destroyed—quite a conservative estimate—the actual loss of copra in this case would be 5·8 per cent. of the whole, and in view of Experiment 14 would represent an avoidable loss.

103 Further, it will be noted (page ~~25~~, Section I) that the control copra of these experiments was generally of better quality than usually produced by the native, so that it is reasonable to assume that the insect damage to this experimental copra was less than it would have been in the case of native copra stored under the usual storekeeper's conditions.

To obtain some idea of what this loss means to the Colony it is estimated that the native produces at least one-third of the Colony's total copra output. The average output for the five years 1926–1930 was 28,500 tons, representing about 9,500 tons of native copra. Using the figure obtained in the storage experiment as representing loss to copra from insect attack, then the loss would be 1,600 tons per annum which at the present price of copra, viz., £9 5s. per ton at Suva, means a monetary loss to the Colony of nearly £15,000 annually.

In conclusion, reference to the *Agriculture Journal* of Fiji, 1930, Vol. 3, No. 2, page 81, will give possible losses to copra in store through mould action. If this is read in conjunction with the present paper, it will be seen that Experiment 14 especially seems to offer a suitable method whereby these enormous losses to both producer and this Colony through the ravages of moulds and insects in copra in store may, with reasonable expectation of success, be averted.

DETERIORATION OF COPRA ON STORAGE.

By C. L. Southall, B.Sc., former Government Chemist, Fiji.

The experiments carried out during the winter of 1927 to determine the loss caused to copra by drying on open vatas pointed to the fact that further loss occurred after the copra was removed from the vata to storage. To determine, if possible, the conditions resulting in the loss and the amount of loss, the following experiments were made:—

A—Change in acidity of three commercially prepared samples of copra.
B—Slow drying on open vatas for 14 days followed by three months' storage.
C—Storage of commercially prepared copra for three months and estimation of loss at intervals.
D—Rapid drying of copra on open vatas and removal to storage for three months.

A—*Change in acidity on storage.*

The loss of copra was unfortunately not determined but nevertheless the results are of interest:—

Copra	23–10–27.		10–12–27.		7–1–28.	
	Water.	f.f.a.	Water.	f.f.a.	Water.	f.f.a.
1	9·1	4·6	4·9	12·2	4·7	11·8
2	7·1	2·9	4·8	4·2	4·7	4·4
3	7·4	2·1	4·8	4·9	4·6	4·9

The copra arrived in Suva on 22nd October, 1927, for shipment to Europe. Sacks of each brand were held back and stored with other copra in a bulk store, being examined at intervals.

B—*Changes during slow drying on open vatas for 14 days followed by storage for three months.*

This experiment was a continuation of one reported to you on 22nd October (Ref. No. 1190/27). On the 14th day the copra was bagged and stored with other copra:

	Slow drying on open vatas.		Storage in presence of other copra.	
	1st day.	14th day.	55th day.	99th day.
Moisture	45·6	8·0	4·8	4·6
Oil content of anhydrous copra .	68·4	69·9	70·6	70·4
Acid in oil (as oleic)	0·2	6·5	9·9	9·8
Loss anhydrous copra	....	10·9	14·6	15·0

C—*Storage of commercially prepared copra for three months and estimation of loss at intervals.*

The copra was taken at random and stored with other copra. Only moisture and loss of copra were determined:—

Copra.	Originally Moisture.	Two months.		Three months.	
		Moisture.	Loss of copra anhydrous.	Moisture.	Loss of copra anhydrous.
1	7·4	4·9	5·1	4·6	5·4
2	6·8	5·1	4·0	4·8	3·9
3	9·3	4·8	8·3	4·6	8·7

D—*Rapid drying of copra on open vatas and removal to storage for three months.*

This experiment was designed to follow as nearly as possible normal working methods in Fiji. Two sacks of copra were dried as rapidly as weather conditions permitted on an open vata and bagged after four days. They were stored with other copra for three months, being tested once during the interval. The first sample was dried during fair weather and the second sample during bad weather, being rained on on each of the four days:—

Copra No. 1.	Drying.		Storage.	
	1st day.	4th day.	47th day.	89th day.
Moisture	45·9	8·8	4·9	4·6
Oil in anhydrous copra	68·7	68·6	69·4	69·3
Free acid in oil as oleic	0·2	2·0	6·8	6·4
Loss anhydrous copra	....	1·1	8·9	9·3
Copra No. 2.				
Moisture	45·7	15·2	5·0	4·8
Oil in anhydrous copra	68·4	68·6	73·0	72·6
Free acid in oil as oleic	0·2	3·2	16·4	16·0
Loss anhydrous copra	....	2·1	20·1	20·8

In all the above experiments allowance must be made for errors. Satisfactory sampling of copra is not easy and no conclusions should be drawn from small discrepancies between the above figures.

Conclusions.—Assuming the tests made to be typical I think the following conclusions may be drawn:—

(1) copra containing less than 6 per cent. moisture does not deteriorate to any great extent when stored in sacks in bulk;

(2) copra containing over 6 per cent. moisture when stored under conditions where it only loses moisture slowly, *i.e.*, in a heap of sacks, deteriorates very considerably. A loss up to 20 per cent. anhydrous copra may occur;

(3) there does not appear to be a simple mathematical relationship between increase in f.f.a. content and loss of copra, although I am of the opinion that the loss of copra is at least equal to the acidity of the oil. In the more normal experiments the proportion of loss of copra to f.f.a. was as 4 to 3.

Acknowledgment.—Thanks are due to Messrs. Brown & Joske for their assistance in the above work.

SECTION II.

By W. J. Blackie, M.Sc., A.I.C., Government Chemist.

This portion of the paper deals more particularly with the chemical side of the problem of copra improvement and in a general way embodies experimental confirmation of the results of direct observation discussed in Section I of this paper.

2. In a previous paper (1) mould damage to copra was discussed in detail and some idea was given there of the commercial losses involved in the methods of preparation utilised in Fiji. The experimental results which follow tend to support many of the arguments advanced in (1), more particularly with regard to the preparation of a stable inhibitory superficial medium which would (*a*) prevent or retard the development of spores during the period of drying, (*b*) preserve the copra during storage and transit.

3. The meat of the coconut is rich in proteins, carbohydrates and fat. The surface of the meat in relation to the water is much softer than the interior and contains the products of proteolytic and hydrolytic enzymes, contained in the coconut water. The quantity of these materials such as soluble sugars, soluble protein decomposition products, &c., varies with the age of the nut and is richest in the germinating nut. When the nut is opened and the meat spread out to dry there is exposed a superficial nutrient medium and under humid conditions many of these products, more particularly the sugars, absorb water. We thus have a surface ready for spore development. Once germinated on a rich medium the organisms establish themselves and their subsequent development is ensured by the liberation of enzymes which catalyse the decomposition of the meat. The nature and extent of these enzymes was discussed in (1). It is impossible to prevent spores coming in contact with the drying meat, therefore the problem resolves itself into (*a*) limitation of spore development and from the storage point of view (*b*) limitation of subsequent mould and insect followed by mould action on the stored copra.

4. The means of attack from the above facts is obvious, also from the theoretical consideration advanced in (1), where the nature of enzymes and enzyme action is discussed in some detail. It was emphasised there the specific nature of enzyme action and its dependence on optimum conditions of hydrogen ion concentration. The amount and extent of enzyme action depends also on the manner of growth of the fungoid body. If this is inhibited in any way then decomposition is not so rapid in spite of the fact that a small quantity of enzyme can catalyse many times its own weight of reaction products. It is also to be realised that optimum conditions are necessary for the development of the spore. These conditions are realised on drying meat unprotected and include hydrogen ion concentration also, but the range for development is much wider than that required for optimum enzyme action. The development of the spore is influenced more particularly by temperature, moisture and sufficiency of food. It is possible that the materials used in this investigation to be described subsequently, may have acted as enzyme inhibitors but this is not considered to be the primary action.

5. It was realised that the methods adopted must be simple, cheap and noticeably effective and that any chemicals used must be non-poisonous, otherwise the process would not be a commercial success with native labour. This naturally limits the field of inquiry from a scientific standpoint.

EXPERIMENTAL.

6. The following sections will be considered in turn:—
(1) sampling, and analytical methods;
(2) sulphuring of copra;
(3) washing of copra with sea water and potassium metabisulphite;
(4)—(*a*) washing with sodium carbonate 5 and 10 per cent. solution;
(*b*) washing with sodium carbonate followed by sulphuring.

7.—(1) *Sampling and analytical methods.*—It is necessary in investigations such as these to obtain representative samples. This is particularly hard with copra, since it is known that oil, free fatty acid and moisture may vary considerably, even in different portions of the same nut. The haphazard methods usually adopted of removing a pound or two of the material from a sack and using this for the analytical operations would be useless here, in as much as the success of the methods depended upon obtaining representative samples for comparison.

8. The methods adopted by the Malay workers were considered too detailed for our purpose and after reviewing these and other sampling methods it was considered that the usual quartering method as modified by us gave fairly good representative samples. The following procedure was therefore adopted. The whole of the material as prepared in Section I of this paper was spread out on a board and after thorough mixing with a spade was quartered in the usual manner until a quantity of about 2 lb was obtained. This was first of all bottled, but later experiments displayed the fact that it kept better if sewed up in a small bag. Moreover, it more nearly represented commercial conditions in storage. From each piece of copra so obtained three pieces $\frac{3}{8}$ in. in diameter were punched out by means of a metal punch. Each piece so removed was sliced up by means of a razor blade into small portions less than one millimeter in thickness. The material so obtained was further mixed and quartered until a representative sample for analysis was secured. Remarkably concordant results were obtained through sampling in this manner. The analysis was carried out in the usual way except that the moisture was determined in a vacuum oven and the oil determined on this dried material. The oil was extracted in a Soxhlet Extractor after being ground up with sand using petroleum ether as solvent. Owing to the fact that (*a*) despite extreme care sand and other particles passed into the extraction flasks, (*b*) the bottoms of the flasks were sometimes covered with a deposit from the boiling water in which the flasks were immersed, (*c*) under high humidity conditions an extraction flask even although suitably counterpoised presents too big a surface for condensation of moisture during weighing, the following procedure was adopted with success. The oil after extraction was evaporated with recovery of solvent to a small volume, the residue was filtered through a small Whatman filter paper, the flask being washed with successive small quantities of petroleum ether poured through the filter paper. The filtrate was collected in a small weighed platinum basin and after gentle evaporation in the water bath last traces of solvent removed in the vacuum oven. Free fatty acid was determined in the usual way by expression solution in neutral alcohol, and titration with $\frac{N}{10}$ Sodium Hydroxide using Phenolthalein as indicator.

9.—(2) *Action of sulphur dioxide on copra.*—A large amount of work has been done on the sulphuring of fruits, &c., in order to preserve them. Except for a limited amount of work carried out in the Philippines (2) and elsewhere, little has been done on the sulphuring of copra. Southall (3), a summary of whose work will be included, carried out experiments with interesting results,

but both his work and that of the Philippine workers suffered from incompleteness. It was therefore thought that a thorough investigation of the claims made for sulphuring copra was necessary since sulphur is a cheap product and readily available in Fiji. The plant described in the first section of this paper was therefore constructed and experiments performed as described there, using varying charges of sulphur and varying times of sulphuring.

10. In order to obtain complete comparison samples of untreated copra were subjected to drying along with the treated material. A control was thus obtained and in almost every case distinct controls were used in each experiment. During the earlier work difficulty was encountered with the sulphur combustion, but after several attempts to obtain complete firing, success attended the use of sulphur mixed with coconut husk as described in Section I. With the heavier charges of sulphur and complete combustion the chamber was soon filled with an atmosphere of sulphur dioxide, and after the completion of the experiment the air in the chamber was still charged with a high content of SO_2. The earlier experiments suffered from incomplete firing and a consequent low percentage of SO_2 in contact with the meat. The trays were constructed and arranged in the chamber to permit of the greatest possible surface of meat coming in contact with the sulphur dioxide charged atmosphere. After sulphuring the copra was dried along with the control and samples were taken, prepared and analysed as described above.

During 1927–28 sulphuring experiments (3) were carried out at Wakaya and Taveuni with a type of chamber similar to that described in Section I of this paper. From the description of the plant as described in the records of this Department it would not appear to have been as suitable as the one used for these experiments, the main features of which were durability, portability and efficiency. Sulphuring was carried out from four to twelve hours with varying quantities of sulphur, not specified. Difficulty was experienced with the combustion, but it was stated that if the sulphur was spread out on a thin plate to a depth of half an inch combustion took place slowly. We could not obtain efficient combustion by this method and therefore adopted the procedure outlined above.

A summary of the experimental results obtained under conditions to be described and the analytical data after preparation and storage for three months is given below.

(1) Copra sun-dried covered at night. The unsulphured meat dried rapidly and was badly burnt, having dried in three days. The sulphured meat remained clear white: burning was absent:—

TABLE I.

	Sulphured when prepared.	After 3 months storage.	Unsulphured when prepared.	After 3 months storage.
Moisture (per cent.).	6·9	5·4	5·1	4·8
F.F.A. (per cent.) ..	0·17	1·6	1·2	3·4
Oil colour	White.	White.	Light yellow.	Light yellow.
Appearance of copra	White.	White with copra bugs in cracks.	Burnt.	Burnt, very dusty, larvæ and copra bugs.

(2) Two samples sulphured and unsulphured, sun-dried for one day, uncovered for one night to heavy rain, then dried for three days:—

TABLE II.

	Sulphured When prepared.	After 3 months storage.	Unsulphured when prepared.	After 3 months storage.
Moisture (per cent.).	5·7	5·1	4·9	4·6
F.F.A. (per cent.) ..	0·34	2·0	7·6	8·1
Oil colour	White	White.	Yellow.	Deep yellow.
Appearance of copra	White.	White, but containing copra bugs and larvæ.	Brown mouldy	Brown, copra bugs and larvæ more extensive.

(3) Sulphured and unsulphured sample placed in a damp shed without air drying. Humidity increased by covering with corrugated iron. Each night for eight nights the iron was removed and copra sprinkled with water. After this period the sulphured sample appeared unchanged, the unsulphured a slimy mass of moulds:—

TABLE III.

	Sulphured When prepared.	After 3 months storage.	Unsulphured when prepared.	After 3 months storage.
Moisture (per cent.).	5·9	5·3	5·1	5·0
F.F.A. (per cent.) ..	0·34	1·79	9·6	11·5
Oil colour	White.	White.	Light brown.	Dark brown.
Appearance of copra	White.	White with larvæ and copra bugs.	Very mouldy and dark.	Dark with more extensive larvæ and copra bugs.

If we summarise these results for the free fatty acid we obtain:—

TABLE IV.

	Sulphured. March—June.	Unsulphured. March—June.
	% %	% %
I	·17 to ·16	1·2 to 3·4
II	·34 to 2·0	7·6 to 8·1
III	·34 to 1·7	9·6 to 11·5

It would therefore appear that sulphuring of copra had much to commend it.

The following are the results of the analyses of the experimental material prepared as described in Section I of this paper. The experiments are more detailed and the results obtained are similar to those described above. In

order to facilitate comparison I have tabulated the results in a manner similar to that in Section I:—

SERIES 1—TABLE V.

Expt. No.	Sample.	Water.	Oil on water free.	F.F.A.
		Per cent.	Per cent.	Per cent.
1	Unsulphured control ..	7·95	67·45	0·88
	Sulphured germinated ..	6·98	68·22	3·29
	Sulphured uncovered ..	8·21	70·54	1·30
	Sulphured covered ..	8·92	68·44	1·76
2	Unsulphured control ..	9·10	63·54	2·37
	Sulphured germinated ..	7·41	65·89	9·75
	Sulphured uncovered ..	8·09	62·93	3·21
	Sulphured covered ..	6·59	67·70	4·31

Note.—The "free fatty acid" figures are expressed as per cent. lauric acid. "Oil on water free" refers to oil on the dry basis.

In this series, the results of which were obtained one month after preparation, it is seen that if anything the control sample is the better with F.F.A. at ·88 as in Experiment No. 1 and 2·37 in Experiment No. 2. According to the F.F.A. figure the control in both cases is 100 per cent. better, although the appearance of the copra suggested very little difference. The germinated material in Experiment No. 2 was extremely poor and it would appear that sulphuring under the conditions described has not the ability to arrest anzyme action once it has commenced in the meat of the germinated nut. This would tend to prove the fact that sulphuring is a surface action.

SERIES 2—TABLE VI.

Expt. No.	Sample.	Water.	Oil on water free.	F.F.A.
		Per cent.	Per cent.	Per cent.
3	Control	8·16	64·09	1·09
	Sulphured uncovered ..	9·03	73·95	5·03
	Sulphured covered ..	8·27	67·08	2·49
4	Control	6·71	64·4	0·61
	Sulphured uncovered ..	8·16	....	5·44
	Sulphured covered ..	6·76	67·5	0·67
5	Control	5·44	69·20	1·22
	Sulphured covered ..	6·50	64·21	0·42
	Sulphured uncovered ..	7·30	66·29	7·25

The figures for this series were obtained six weeks after preparation of material. In Experiment No. 3 the control would appear to be the best sample. In Experiment No. 4 there is very little difference between the control and sulphured covered, while in Experiment No. 5 the sulphured covered is the best sample, although the control was quite good. It would therefore appear that the chemical evidence bears out the observations made on Series 2 in Section I of the paper.

SERIES 3—TABLE VII.

Expt. No.	Sample.	Water.	Oil on water free.	F.F.A.
		Per cent.	Per cent.	Per cent.
6	Sulphured covered ..	6·50	64·6	0·83
	Sulphured uncovered ..	8·50	69·2	4·37
	Control	5·05	70·3	0·76
7	Germinated	5·8	63·4	0·67
8	Sulphured covered ..	6·11	65·6	2·68
	Sulphured uncovered ..	8·08	66·9	21·39
	Control	10·00	70·1	....
8A	Sulphured covered ..	7·54	69·26	1·00
	Control	7·22	64·8	10·72
11	Sulphured covered ..	10·00	68·7	3·94
	Control	7·22	64·8	10·72

The results for this series were obtained 2½ months to 3 months after preparation and bagging. In Experiment No. 6 of this series the control appears to be every bit as good as the sulphured product, but enzyme action in the germinated sample, experiment No. 7, appears to have been arrested with the production of an excellent sample. The sulphured products in 8A and 11 are much superior chemically to the control when it is considered that Experiment No. 11 was completed three months after the preparation of the material. The water content is high in the sulphured copra in Experiment No. 11 due to the wet conditions under which it was prepared, nevertheless with this high water content mould damage on the basis of the F.F.A. figure is 2·73 times less than the control, with only 7·23 per cent. of water. These figures were re-determined two months later, that is, five months after the preparation of the sample, with the results displayed in Table No. VIII. The control sample had markedly deteriorated during this period. It is therefore seen that the water content on storage has dropped from 10 to 3·93 and by sulphuring the F.F.A. has only increased to 4·22, that is, 7 per cent. increase.

The original intention was to repeat the determinations as obtained above three months afterwards, but pressure of other work forbade this for every case. In any event each series was complete in itself.

In the case of Series 3, determinations were made three months after the material was bagged. Moisture and F.F.A. were re-determined on the more important samples with the following results:

TABLE VIII.

Expt. No.	Nature of sample.	Three months after preparation.		Five months after preparation.	
		Water.	F.F.A.	Water.	F.F.A.
		Per cent.	Per cent.	Per cent.	Per cent.
6	Sulphured covered ..	6·50	0·83	4·06	0·98
	Sulphured uncovered ..	8·50	4·37	4·74	5·36
	Control	5·05	0·76	3·92	1·04
8A	Sulphured covered ..	7·54	1·00	4·23	1·51
	Control	Badly damaged by mould action.			
11	Sulphured covered ..	10·00	3·94	3·93	4·22
	Control	7·22	10·72	Badly attacked by moulds.	

The control in sample No. 6 gave a better figure for F.F.A. (1·04 per cent.) than the condition of the material would suggest, since it was a very inferior looking article. The percentage increase in acidity 18·1 and 36·9 for the sulphured covered and control respectively gives a better indication of the state of the material. The sulphured covered in Experiments Nos. 8A and 11 had increased in per cent. acidity 51 and 7 respectively. So far no mention has been made of the sulphured uncovered material. On consulting the tables above it is seen that this copra, from Experiment No. 3 onwards from the point of view of the F.F.A. figure, is much inferior to either the control or the sulphured covered. The high figure of 21·39 per cent. of free acidity is reached with the sulphured uncovered product, whereas the covered material contained only 2·68 per cent. F.F.A. These results do not strictly compare with those of Southall (3) (see Table III above), since we did not protect the sulphured uncovered product in any way, whereas his material was uncovered for an experimental period and then dried normally. It is thus to be noted that sulphuring does not protect the copra if the latter is uncovered to all weathers. It does, however, assist materially in producing a good grade copra under high humidity conditions if care is taken in protecting against rain and dew falling intermittently on the material during drying operations. The sulphured uncovered product more nearly represents usual quality copra as produced in Fiji. The figures also display the fact that with care a fair grade copra can be produced without sulphuring. Some of the controls above were quite good even after three months storage but it is to be remembered that these controls were protected at all time during drying from the weather. The sulphured product scores over the unsulphured material dried under similar conditions in (*a*) having a cleaner almost bleached appearance, (*b*) lasting better on storage, (*c*) drying to a better grade material under high humidity conditions, (*d*) being a little less prone to insect attack on storage. It does not, however, in all cases appear to have the same crisp appearance nor is it so easily fractured as a good quality sun-dried sample. It is in fact generally quite leathery and bends rather than fractures. These points are of commercial importance, but the quality of the material outweighs these apparent physical characteristics. The sulphured meat appears also to shrink less on drying and it can contain a higher water content than the unsulphured material without excessive mould action.

With regard to the chemical action of sulphuring, little can be said as yet. The primary action is no doubt the production of an acid surface which inhibits the development of spores. Nevertheless, when spores do develop on the strongly sulphured meat the fungus body does not flourish so well as on untreated meat, also the sulphured product has a greater resistance against mould action on storage, after a period when it can reasonably be considered that surface resistance has ceased. From these observations it would appear that sulphuring has a more deep seated effect on the copra inhibiting internal breakdown and external enzyme action.

It seems almost probable that some type of enzyme inhibitor is produced by the sulphuring of wet meat. It did not appear necessary at the commencement of this work to determine the quantities of sulphur over and above that normally present in the copra, also the type of sulphur compounds, but in the light of the results obtained such an examination would make an interesting contribution to our present knowledge of the process.

In the above experiments the F.F.A. figure was taken as an index of quality rather than the oil figure. The nuts used in the experiments were of all ages, and quartering was not resorted to in setting aside the material

for drying, nor were equal quantities of material set aside so that in any one series the composition of the copra would differ to a greater or lesser extent. This is well displayed in the oil figures obtained. The F.F.A., which is a measure of oil decomposition, would not be so effective.

From the results of these determinations it can be concluded:—

(1) Sulphuring of copra, using the plant described under the conditions laid down in Section I for Experiments 8 and 11, produced an excellent quality copra.

(2) After storage for five months the sulphured product was in appearance superior to untreated copra prepared by the usual methods adopted in Fiji.

(3) On the basis of the F.F.A. figure sulphured copra lasts better on storage and is a commercial article when untreated Fiji copra has materially decomposed.

(4) If care is taken during drying operations a good quality sun-dried copra can be made without sulphuring, but this does not keep so well on storage. This conclusion is based upon results obtained with our controls, but does not hold for copra as prepared by certain planters in Fiji.

(5) Sulphured copra uncovered to weather during drying does not resist mould action, but for intermittent showers it lasts better than normal Fiji copra.

(3) *Washing of copra with sea water and potassium metabisulphite.*—In the introduction to this section of the paper it was pointed out in paragraph 4 that when the wet meat is laid out to dry there is exposed to spore action a surface containing soluble carbohydrates and protein hydrolytic products. It was therefore thought by washing the meat before drying that a large amount of these products might be removed and that therefore mould action would be limited to some extent. It has been frequently observed that copra made near the coast, where sea breezes containing salt spray can come in contact with it, has a better appearance than that prepared inland. The obvious conclusion is that the sea air in some way limits mould action. There would appear to be some slight scientific grounds for this conclusion since in a recent paper (H. R. Curran (4)) it has been shown that increase of osmotic pressure of the medium by sodium chloride has a retarding effect on the development of bacterial spores. It was therefore decided to wash copra with sea water and dry it in the usual manner. The following results were obtained:—

TABLE IX.

Expt. No.	Sample.	Water.	Oil on water free.	F.F.A.
		Per cent.	Per cent.	Per cent.
9	Control	7·22	64·87	10·72
	Sea water single wash ..	Rotted through by fungi.		
12	Sea water double wash ..	8·18	62·65	3·18

The single washed sample decomposed early, but the double washed material appeared quite good when prepared and lasted longer. It had, however, become almost worthless after five months' storage and much inferior to the control which, as stated above in Table 8, was badly attacked by moulds, copra bugs and larvæ after five months' storage.

It would therefore appear that washing with sea water had no effect in arresting mould action. These experiments were conducted during bad weather and drying took from 14 to 17 days. It would be necessary to repeat this work under better drying conditions.

It was thought that better results might be obtained by washing with potassium metabisulphite. Metabisulphites are considered to be extremely stable non-hygroscopic substances and are unaffected by air. It was realised that this material is expensive and could possibly not be used commercially, but we had found no reference to its use as an enzyme inhibitor. The sample of metabisulphite which we used appeared to be decomposing with the liberation of sulphur dioxide and it was considered that a type of automatic sulphuring might result from its use, especially in contact with drying meat.

The results, however, were extremely unsatisfactory for both the singly and doubly washed materials which were very badly decomposed, soon after preparation. No determinations were made. However, drying took 19 days with the singly washed and 12 days with the doubly washed. These conditions, as with the sea water washed, were abnormal and a better product may have resulted under more normal drying conditions. The work was not continued with at this stage.

(4) *Washing with sodium carbonate* 5 *and* 10 *per cent. solution.*—Considering that the primary action with sulphuring is the formation of an acid inhibiting surface it was argued that similar results could be obtained with an alkaline surface. It was also thought that by washing with an alkaline reagent of sufficient strength that the dual purpose of removing nutrient material from the surface of the meat and at the same time creating an alkaline surface would be served. It has been stated by Webb (5) that in equal concentrations of the ions the O.H. ion appears to be relatively more toxic to the spores he studied than H. ions. He used, of course, artificial media. Levine Buchanan and Toulouse (6) have shown that by the addition of sodium chloride, sodium carbonate and sodium phosphate to caustic soda contained in a suitable medium bacteria were killed more rapidly. Therefore it is the caustic soda itself, not the O.H. ions which, by penetrating the cells, caused death. Meyer (7), however, considers that the action is due to the concentration of the hydroxyl ions. It would not appear that the sodium and potassium ions have any effect, although it is pointed out by Marloth (8) that sodium ions in high concentration are toxic.

The copra prepared by washing in 5 and 10 per cent. sodium carbonate solutions as described in Section I were analysed after five months' storage. The material was in splendid condition and the results obtained were as follows:—

TABLE X.

Expt. No.	Sample.	Water.	Oil on water free.	F.F.A.
		Per cent.	Per cent.	Per cent.
14A	Sodium carbonate 5% ..	4·69	63·02	1·19
	Sodium carbonate 10% ..	5·13	64·08	0·98

It is thus seen that 5 per cent. and 10 per cent. carbonate solutions were effective in limiting mould action, the figure 0·98 being very satisfactory for copra of this age. As far as could be seen this material, except for slight discolouration, appeared sound and was classed as first grade.

Some of the material from the 5 per cent. and 10 per cent. carbonate washed, was sulphured. The results obtained were striking and a product was produced that entirely resisted mould action. It had the bleached appearance of sulphured copra and the analytical figures obtained for the 10 per cent. washed and sulphured after five months' storage were as follows: Moisture, 5·09 per cent.; oil on water free, 61·93; F.F.A., 1·42. This product was considered the best obtained and was classed as extra first grade. It had entirely resisted mould action after five months' storage.

As far as the analytical data is concerned the " carbonated sulphured " would not appear to be in any way superior to the unsulphured carbonated, but its appearance is very much better and it showed no mould development after five months' storage.

SUMMARY.

It has been shown (1) that washing copra with 5 and 10 per cent. solutions of sodium carbonate produces good quality material that markedly resisted mould growth, (2) by washing with 10 per cent. sodium carbonate followed by sulphuring a first grade material was obtained which appeared to entirely resist mould action, (3) the sulphured carbonated copra had a better appearance than the carbonated. It also dried well and had the crisp and easily fractured nature of good quality sun-dried.

In attempting to explain the underlining process of the various attempts to produce a mould-free copra one is faced with lack of experimental details. The experiments outlined above were considered more from the commercial aspect than the scientific. Nevertheless, certain facts were adduced which throw a little light on the matter. Fifty grammes of the materials prepared as above were washed with 50 c.c.s. of distilled water 12 months after preparation and a qualitative analyses made of filtrates. Also 20 grammes of the internal material obtained by removing the entire exposed surfaces as completely as possible were also washed with 25 c.c.s. of distilled water and the filtrates qualitatively analysed. The results obtained are as follows:—

TABLE XI.

	Surface washed.				Internal washed.			
	Control.	Sulphured.	Sul. Carb.	Carb.	Control.	Sul.	Sul. Carb.	Carb.
Carbonate ..	Absent	Absent	Trace	Present	Absent	Absent	Trace	Present
Sulphates ..	Absent	Present	Present	Absent	Absent	Present	Present	Absent
Sulphites ..	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent

Only small amounts were present, but the substances were definitely recognised. Of the metallic ions only sodium and possibly potassium were recognised. Calcium magnesium aluminium and iron did not appear to be present in sufficient quantities to be recognised. These results are interesting for it seems evident, as pointed out above, that sulphuring is not altogether superficial and the same would apply to the action of sodium carbonate. Quantitative estimations were not made. It appears (1) that in the sulphured product sulphur dioxide permeates the whole of the meat and in solution comes in contact with possibly potassium soluble salts which are known to be present in coconut water, forming potassium sulphite which is oxidised to the sulphate. The exact nature of the reaction is not known except that the sulphate ion is definitely recognised after twelve months' storage; (2) the carbonate ion permeates the meat; (3) sulphate, probably sodium sulphate, is found in the interior of the meat after washing with sodium carbonate and sulphuring.

Taking these rather scanty facts into consideration and from the foregoing discussion under the various sections it seems as if the main actions are:—

(1) The sulphurous acid acts first in producing a superficial medium of high H. ion concentration which retards development of spores. The $S.O._3$ ion also acts tocixologically on spores through the inhibition of enzyme action and on a surface of high concentration of salt produced by evaporation spore development may also be decreased by increase of osmotic pressure. The toxicological action is enhanced by oxidation to the sulphate and the keeping power is enhanced by the presence of this toxicological ion within the meat.

(2) The washing with sodium carbonate produces a superficial medium of high O.H. ion concentration which retards the development of spores. This surface action is greater than with the H. ion concentration produced by sulphurous and sulphuric acid owing to the greater toxicity of the O.H. ion. The presence of sodium carbonate within the meat assists storage, but it is considered that the toxic action of this ion is less than that of the sulphate or sulphite ion and that its chief internal action is the presence of a high O.H. ion concentration. Osmotic pressure may also superficially play its part here.

(3) The washing with sodium carbonate followed by sulphuring retards development, as described above, but the presence in comparatively high concentration of sodium sulphate gives the product greater resisting power owing to the presence of the highly toxic sodium and sulphate ions.

The difference between the sulphured product and the sulphured carbonated product is one of degree, also the presence of more toxic sodium ion in greater concentration.

It is to be noted here that in the case of "carbonate sulphured" product that all the spores that normally affect copra are prevented from developing.

CONCLUSION.

There are many opinions as to the exact nature of the reactions of fungi to H. and O.H. ions. It is considered by Boeseken and Waterman (9) that the action of the H. ion is to precipitate the negatively charged albumin and lecethin colloids in the cell wall of the spore, and it is possible that the O.H. ion acts similarly by discharging the positively charged colloids. Marloth (8) suggests that "since the proteins in the protoplasm are amphoteric in nature it may also be possible that the influence of the hydrogen and hydroxyl ion is such as to reverse the charge on certain proteins causing a disruption of the protoplasm within the cell." The opinion is also expressed by Marloth (8) with reference to the action of sodium bicarbonate on penicillium Italicum that the decay of citrus fruit is prevented by the fact that when the spores develop or commence to develop there is present on the rind a surface film of saturated bicarbonate solution which acts on the proteplasm of the thin wall germ tube or at that point on the spore where the wall is thinned for the emergence of the germ tube. This action is probably more important than the osmotic action discussed above, and it is considered that sodium carbonate and sulphate acts in a similar manner, also that the internal action is somewhat similar within the dried meat of the copra.

From these experiments it would appear that washing with sodium sulphate would produce a good grade copra, and experiments will be instituted to prove this point.

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EXAMINATION BY THE IMPERIAL INSTITUTE, LONDON, REMARKS AND CONCLUSIONS.

MOST of the samples had suffered somewhat in appearance owing to insect attack. When allowance has been made for this defect, the following conclusions can be drawn from the results of the examination.

1. *Effect of Sulphuring* (*Experiments* I *to* VIII—A *and* XI).—The best of the sulphured samples dried under cover was No. VIII—A, sulphured and covered, which had been treated with 12 oz. of burning sulphur for nine hours. This sample was a duplicate of No. VIII, sulphured and covered, but was of better appearance.

2. Although No. VIII—A, sulphured and covered, is better than its control, it is not quite equal to the standard of the control to No. III. From this it might be concluded that the sulphuring of the copra before drying had not produced a better product than can be prepared without this pretreatment.

3. No. VIII—A, sulphured and covered, was treated with as much burning sulphur, and for as long a time as any of the sulphured and covered samples; in fact, its treatment was more severe than any other of such samples, except its duplicate in Experiment VIII. It might therefore be expected that a slight but gradually increasing improvement would be shown by the samples in proportion to the amount of sulphur used and the length of the treatment. Such an improvement is in fact shown in most cases. Where the samples have all received the same amount of burning sulphur, the effect produced by the varying lengths of the treatment is not very apparent.

4. One of the objects of sulphuring the copra before drying is doubtless to prevent the copra from becoming mouldy during drying. Treatment of the material for this purpose would, however, appear to be unnecessary, as none of the controls showed mould.

5. One effect of sulphuring the copra and drying it under cover would appear to be to reduce the acidity of the extracted oil. The effect on the colour of the oil and the meal is not uniform; in some cases the oils from the treated copras are better than those from the control, and in other cases not so good.

6. Any good effect that might be produced by sulphuring is undone by drying the copra uncovered. Sulphured and uncovered samples generally have a poorer appearance and yield an oil with a higher acid value and of poorer colour than those that have been sulphured and dried under cover. It is to be noted, however, that the oil content of the sulphured and uncovered samples is generally slightly higher than that of the control and of the sulphured and covered samples. Many of the sulphured and uncovered samples were mouldy.

7. The three vara samples were rather thinner than the controls, and yielded oils with an acid value slightly higher than that of the oils from the sulphured and covered samples; otherwise they were very similar to the latter samples.

8. *Sea-water* (*Experiments* IX *and* XII).—The effect of sea-water does not appear to be as good as that of sulphuring. The double-washed sample was slightly darker both as regards the inner surface and internally than the once-washed sample, and gave a browner oil and a meal of poorer colour.

The once-washed, uncovered sample had a slightly higher oil content than the control or the covered sample, and yielded a foxy-red oil of very high acidity and a meal of poor colour.

9. *Potassium meta-bisulphite* (*Experiments* X *and* XIII).—Treatment with meta-bisulphite does not show any advantage over sulphuring. No. XIII, treated with 100 c.c. of solution, was not so good as No. X treated with 60 c.c. of solution, and gave a foxy-red oil of higher acidity and a meal of poorer colour.

10. *Sodium carbonate* (*Experiments* XIV *and* XIV—A).—These samples are better than the control and compare very favourably with the sulphured and covered samples of the earlier experiments. Sodium carbonate has the effect of reducing the oil content slightly, and when a sample so treated is sulphured the acid value of the extracted oil is lowered. The sulphured samples are slightly better in appearance than those which were only washed. Varying the amount of carbonate used does not produce any appreciable effect, though the sulphured sample treated with 10 per cent. is slightly better than that treated with only 5 per cent. No. XIV, washed and sulphured, is very slightly better than No. VIII—A, sulphured and covered.

11. *Caustic soda* (*Experiments* XV *and* XV—A).—These samples, like those of Experiments XIV and XIV—A, are better in appearance than the control, and compare very favourably with the sulphured and covered samples. They are very similar to those treated with sodium carbonate. In these cases also treatment with alkali has slightly reduced the oil content, and the sulphured samples yielded oils with lower acid values than the control. The sulphured samples are slightly better in appearance than those which were only washed. The sulphured sample, treated with 2½ per cent. solution of caustic soda, is similar to No. XIV washed with 10 per cent. sodium carbonate and sulphured. No. XV—A, washed and sulphured, is very slightly better in appearance than No. VIII—A, sulphured and covered.

12. *General conclusions.*—These experiments show that no advantage is obtained by treating copra, before drying, with sea-water or with potassium meta-bisulphite.

13. Copras treated with alkali and sulphured before drying give better products than the untreated control samples, and the indications are that treatment with the fumes of burning sulphur for nine hours before drying under cover definitely improves the quality of the resulting copra.

14. The control samples and the sulphured samples dried under cover are generally of better appearance than samples of plantation Fiji copra previously examined at the Imperial Institute.

COMMENTS.

1. The above remarks and conclusions bear out in the main the results obtained during this investigation.

2. It is, however, to be understood that a strict comparison of the findings of the Imperial Institute with our results is not possible, owing to the fact that the weather conditions were not fully appreciated.

3. In dealing with the " objects of sulphuring copra " the suggestion is misleading, being based on the fact that the copra in question had an average moisture content of 4 per cent. on examination in London. Such copra does not favour mould growth and the moulds which had developed when moisture was 12 per cent. and over would tend to die out when the copra dried, leaving, where mould colour permitted, a stain to indicate previou infection. Also in paragraph 2 of the summary reference is made to the

fact that although No. VIII—A, sulphured and covered, is better than its control, it is not quite equal to the standard of the control of No. III. It is readily seen that it was essential to have a control in each case, owing to variations in the compositions of the meat (which was made as uniform as possible for each individual series) and drying conditions from experiment to experiment. It is, therefore, not correct from our point of view to compare the control of one experiment with the controls and treated products of other experiments.

4. It has been frequently noted here that very badly decomposed copra has a higher oil figure than one would expect. This was noted during work with regard to the sulphured uncovered (see Tables, Section II), and was referred to by the Imperial Institute in paragraph 6 above. This high oil figure is, however, only apparent and may be due to either a greater selective rate of decomposition of the components other than oil in the copra, with the escape of volatile products, or to products other than oil appearing in the petroleum ether extracts as a result of this decomposition. This point is very interesting, for the oil contents of sulphured uncovered samples appeared to be very much higher than the controls. It would appear from this that the treatment, sulphur di-oxide and excess moisture favoured the selective decomposition of components other than oil in the meat.

5. Paragraphs 10 and 11 of the Remarks and Conclusions dealing with the sodium carbonate and caustic soda treatments make very interesting reading. The Imperial Institute have noted the important point that the acid value of the oil has been lowered by treatment with alkali and sulphuring. This bears out our conclusions obtained many months previous to the Institute's examination and points to the fact that the treatment inhibits in a marked manner the production of f.f.a. from the oil, that is, that mould damage has been reduced to a minimum. It was stated by the Imperial Institute in their detailed report that experiment No. XIV (washed with sodium carbonate 5 per cent. and sulphured) was free from insect attack. This important fact was not mentioned in the conclusions and remarks quoted above. We had certified the sample as free from insect and mould attack on July 21st, 1930 (see Series 4, page 101) and it was again certified as free from insect attack on arrival in London—eight months after bagging. During this long period the sample was in intimate contact with badly infested copra. The estimated loss on storage due to insect damage has been dealt with in Section I—B, page 105, and the suggestion is that the process involved in Experiment XIV deserves investigation on commercial lines. It is encouraging to learn that the " carbonated " samples are better than the controls and also No. XIV, washed with sodium carbonate and sulphured, is slightly better than VIII—A, sulphured and covered.

6. Considering the general conclusions of the Imperial Institute quoted above the comment concerning copra treated with sea-water is only correct for the conditions obtaining during these particular experiments, the controlling factor being the weather.

7. With regard to the time necessary for sulphuring it would appear from the fact stated in Section I, page 103, that nine hours does not appear to be necessary.

8. The statements with regard to the treated samples are in accord with our own, except that in our opinion, considering all available information, including the results obtained by the Imperial Institute with regard to freedom from insect attack and low acid value of extracted oil, that the samples washed with five per cent. sodium carbonate and sulphured is much superior to the other treated material.

9. The report received from the Oil Crushers per the Imperial Institute letter, 0/2295 of the 30th July, 1931, gives further striking confirmation to the findings of this investigation and is given in full below:—

"With reference to my letter of the 7th July, a report has now been received from the firm of copra brokers. The samples forwarded to them were labelled from A to H and represented the results of the experiments mentioned below:—

A—Control to Exp. III, unsulphured, sundried.
B—Exp. VIIIa, sulphured, covered.
C—Exp. III, sulphured, uncovered.
D—Exp. VII, sulphured vara, covered.
E—Exp. IX, sea water, once washed, covered.
F—Exp. X, Potassium meta-bisulphite.
G—Exp. XIV, Sodium carbonate.
H—Exp. XVa, Sodium hydroxide.

The brokers stated that they had submitted the samples to a firm of oil crushers in London, who reported as follows:—

We have received your letter of last month together with copies of letters to you from the Imperial Institute and also eight samples of Fiji copra. We have examined these samples and the analyses of them from the point of view of the crusher, and make the following observations:—

Samples E and F are about equal to what we know as F.M.S. Plantation Fiji Copra.

Sample C although high in oil content, has its value reduced on account of the very high percentage of F.F.As. in the oil, and this appears to be directly due to leaving it exposed and being uncovered at night.

Of the other samples, D appears to be the most valuable on account of its high oil content.

Samples A, B, G and H are deficient in oil, but are good from the point of view of F.F.As. in the oil and it may be only a coincidence that the low oil content and the low F.F.A. content exist together in these samples. We do not see why the preservative treatment should reduce the oil content of the copra.

It appears to be important to protect the copra from rain and cover it at night, and the use of burning suphur as a preservative has a good effect."

COMMENTS.

10. It is mentioned above that Samples A, B, G and H are deficient in oils. We have noted this (see Tables, Section II) as also have the Imperial Institute. It is probably due to the type of copra used, since Sample A above, which was untreated, was also low in oil. We agree with the remarks of the Oil Crushers that there appears to be no reason why the preservative treatment should reduce the oil content. May this also not be due to the fact that decomposition is so limited that we are here really dealing with actual oil content?

11. In conclusion the remark of the Oil Crushers with regard to samples E and F "are about equal to what we know as F.M.S. Plantation Fiji Copra" gives some idea of the type of copra exported from Fiji. We considered these samples to be particularly bad, so much so, that we could not analyse them several months after preparation. It would appear from the remarks made by the Oil Crushers that distinct advances have been made with regard to the preparation of better quality material, having regard to the commercial aspect of the subject.

CONTENTS.